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R COMMISSIONER TRAINING MANUAL

MAY 1998

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
48 NORTH LAST CHANCE GULCH
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WATER CONVERSION TABLE

VOLUME UNITS

The standard unit of volume is acre-feet (ac-ft).

1 acre-foot is equivalent to:

325,851 gallons

43,560 cubic feet

FLOW RATE (DISCHARGE) UNITS

The legal unit for flow rate or discharge is cubic feet per second (cfs).

1 cfs is equivalent to:

40 miner's inches in Montana

448.8 gallons per minute (gpm)

1.98 acre-feet per day

The commonly used unit for flow rate or discharge is miner's inches.

1 miner's inch in Montana is equivalent to:

1/40 cubic foot per second (cfs)

11.22 gallons per minute (gpm)

1/20 acre-foot per day

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MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
48 NORTH LAST CHANCE GULCH
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PREFACE

This training manual was prepared as required by House Bill No. 463 (Mont. Code Ann. § 85-5-111 (1989). This statute requires the Department of Natural Resources and Conservation (DNRC), in cooperation with the Montana Supreme Court, the Montana Water Courts, the District Courts of Montana, the Montana university system, and other appropriate state and federal agencies, to develop an annual water commissioner training seminar, a training manual, and an outreach program that identifies persons who might serve as water commissioners.

The statute also requires the department to develop and implement a similar program and training manual for water mediators. The water mediation requirements have been completed separately from the water commissioner training information to eliminate confusion regarding the duties and responsibilities of each.

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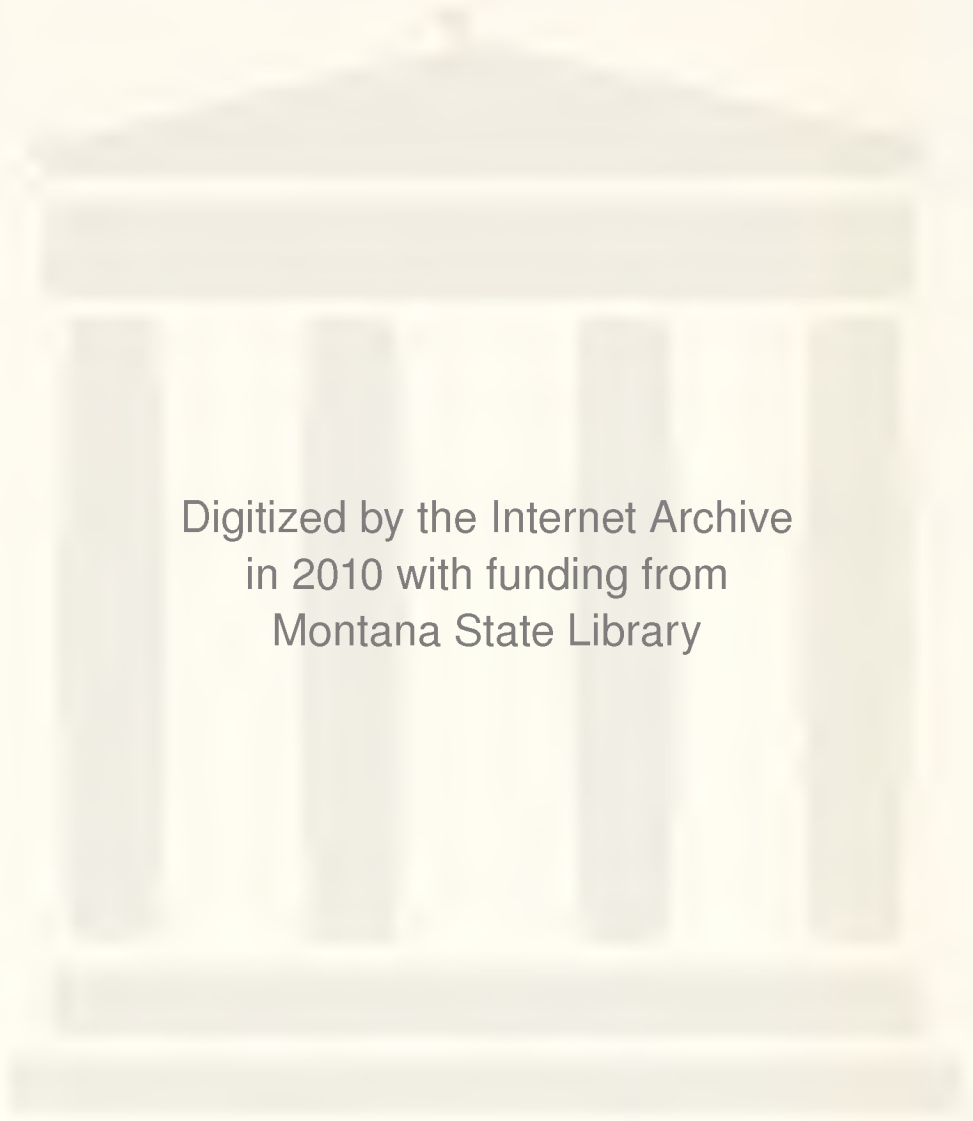

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INTRODUCTION

The 1989 Montana Legislature passed a law creating a program to identify and train water commissioners. The *Water Commissioner Training Manual* is part of the training and will be used in conjunction with the Water Commissioner Training Seminar. It has been assembled to provide water commissioners with the educational and reference materials used in the field to assist them in equitably distributing the waters of Montana within their jurisdictions.

This manual is distributed in various water commissioner workshops held throughout the state. Your comments and suggestions for improving this manual would be greatly appreciated. Please submit your suggestions to the Water Commissioner Program, DNRC, P.O. Box 201601, Helena, MT 59620-1601. It is DNRC's goal to assemble valuable training materials that will assist water commissioners in their daily duties of water measurement and distribution.

DUTIES

WATER COMMISSIONERS AND WATER MEDIATORS

TITLE 85
CHAPTER 5

WATER COMMISSIONERS AND WATER MEDIATORS

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85-5-407. Appointment of water commissioner after final decree.
85-5-408. Apportionment of costs.

Part 1

Appointment and Duties

85-5-101. Appointment of water commissioners. (1) Whenever the rights of persons to use the waters of any stream, ditch or extension of ditch, watercourse, spring, lake, reservoir, or other source of supply have been determined by a decree of a court of competent jurisdiction, including temporary preliminary, preliminary, and final decrees issued by a water judge, it is the duty of the judge of the district court having jurisdiction of the subject matter, upon the application of the owners of at least 15% of the water rights affected by the decree, in the exercise of his discretion, to appoint one or more commissioners. The commissioners have authority to admeasure and distribute to the parties owning water rights in the source affected by the decree the waters to which they are entitled, according to their rights as fixed by the decree and by any certificates and permits issued under chapter 2 of this title. When petitioners make proper showing that they are not able to obtain the application of the owners of at least 15% of the water rights affected and they are unable to obtain the water to which they are entitled, the judge of the district court having jurisdiction may, in his discretion, appoint a water commissioner.

(2) When the existing rights of all appropriators from a source or in an area have been determined in a temporary preliminary decree, preliminary decree, or final decree issued under chapter 2 of this title, the judge of the district court may upon application by both the department of natural resources and conservation and one or more holders of valid water rights in the source appoint a water commissioner. The water commissioner shall distribute to the appropriators, from the source or in the area, the water to which they are entitled.

(3) The department of natural resources and conservation or any person or corporation operating under contract with the department or any other owner of stored waters may petition the court to have stored waters distributed by the water commissioners appointed by the district court. The court may make an order requiring the commissioner or commissioners appointed by the court to distribute stored water when and as released to water users entitled to the use of the water.

(4) At the time of the appointment of a water commissioner or commissioners, the district court shall fix their compensation, and the owners and users of the distributed waters, including permittees and certificate holders, shall pay their proportionate share of fees and compensation. The judge may include the department in the apportionment of costs if it applied for the appointment of a water commissioner under subsection (2).

(5) Upon the application of the board or boards of one or more irrigation districts entitled to the use of water stored in a reservoir which is turned into the natural channel of any stream and withdrawn or diverted at a point downstream for beneficial use, the district court of the judicial district wherein the most irrigable acres of the irrigation district or districts are situated may appoint a water commissioner to equitably admeasure

and distribute stored water to the irrigation district or districts from the channel of the stream into which it has been turned. A commissioner appointed under this subsection has the powers of any commissioner appointed under this chapter, limited only by the purposes of this subsection. His compensation is set by the appointing judge and paid by each district and other users of stored water affected by the admeasurement and distribution of the stored water. In all other matters the provisions of this chapter apply so long as they are consistent with this subsection.

History: En. Sec. 1, Ch. 43, L. 1911; re-en. Sec. 7136, R.C.M. 1921; amd. Sec. 1, Ch. 125, L. 1925; re-en. Sec. 7136, R.C.M. 1935; amd. Sec. 1, Ch. 187, L. 1939; amd. Sec. 1, Ch. 231, L. 1963; amd. Sec. 39, Ch. 452, L. 1973; amd. Sec. 1, Ch. 51, L. 1975; R.C.M. 1947, 89-1001(1) thru (3), (5), (6); amd. Sec. 1, Ch. 444, L. 1979; amd. Sec. 1, Ch. 246, L. 1983; amd. Sec. 1, Ch. 468, L. 1989; amd. Sec. 7, Ch. 604, L. 1989.

Cross-References

Water Judges, Title 3, ch. 7, part 2.
Appointment of Water Commissioner after final decree, 85-5-407.
Apportionment of costs, 85-5-408.
Board power to provide sufficient water, 85-7-1907.

85-5-102. Appointment of chief commissioner. When the judge of the district court shall appoint two or more commissioners to admeasure and distribute the waters mentioned in the preceding section, he may appoint one of them chief commissioner and empower him to exercise direction and control over the other or others in the discharge of their duties. The judge may depose the one appointed chief commissioner from that position and appoint another in his stead whenever it appears to the judge that better service may be given the water users by making the change.

History: En. Sec. 2, Ch. 43, L. 1911; re-en. Sec. 7137, R.C.M. 1921; re-en. Sec. 7137, R.C.M. 1935; R.C.M. 1947, 89-1002.

Cross-References

Appointment of Water Commissioners, 3-7-211, 85-5-101.

85-5-103. Oath and bond. Each water commissioner so appointed by the court shall subscribe and file with the clerk of the district court an oath of office before commencing the discharge of his duties as commissioner and shall likewise file with said clerk a bond executed by himself, with two or more sureties, in such sum as the judge of said court may designate, to insure the faithful discharge of his duties.

History: En. Sec. 3, Ch. 43, L. 1911; amd. Sec. 1, Ch. 12, Ex. L. 1919; re-en. Sec. 7138, R.C.M. 1921; re-en. Sec. 7138, R.C.M. 1935; R.C.M. 1947, 89-1003.

Cross-References

Oaths, Title 1, ch. 6.
General duties of Clerk of District Court, 3-5-501.
Suretyship, Title 28, ch. 11, part 4.

85-5-104. Term of office. Every water commissioner so appointed shall hold his office for such time during the irrigation season of each year

as may be designated by the judge in the order making such appointment. The judge, in his discretion, shall fix the date of the commencement of such term and may, in his discretion or when requested in writing by at least three persons entitled to the use of such waters, change the term for closing of the commissioner's service.

History: En. Sec. 4, Ch. 43, L. 1911; amd. Sec. 1, Ch. 116, L. 1921; re-en. Sec. 7139, R.C.M. 1921; re-en. Sec. 7139, R.C.M. 1935; amd. Sec. 1, Ch. 68, L. 1955; R.C.M. 1947, 89-1004.

Cross-References

Appointment of Water Commissioners, 3-7-211, 85-5-101.

85-5-105. Power and duty to distribute water. Upon the issuance of such order, the water commissioner or commissioners shall have authority and it is hereby made his or their duty to admeasure and distribute to the users thereof, as their interests may appear and be required, the stored and supplemental waters stored and as released by the department of natural resources and conservation under provisions of chapter 1 of this title, to be diverted into and through said streams, ditch or extension of ditch, watercourse, spring, lake, reservoir, or other source of supply in the same manner and under the same rules as decreed water rights are admeasured and distributed. Such water commissioner or commissioners and the owners and users of such stored and supplemental waters shall be bound by and be subject to the provisions of this chapter and all acts amendatory thereof and supplemental thereto; provided, that the admeasurements and distribution of such stored and supplemental waters shall in no way interfere with decreed water rights. The purpose of parts 1 through 3 of this chapter is to provide a uniform, equitable, and economical distribution of adjudicated, stored, and supplemental waters.

History: En. Sec. 1, Ch. 43, L. 1911; re-en. Sec. 7136, R.C.M. 1921; amd. Sec. 1, Ch. 125, L. 1925; re-en. Sec. 7136, R.C.M. 1935; amd. Sec. 1, Ch. 187, L. 1939; amd. Sec. 1, Ch. 231, L. 1963; amd. Sec. 39, Ch. 452, L. 1973; amd. Sec. 1, Ch. 51, L. 1975; R.C.M. 1947, 89-1001(4).

Cross-References

Priority, 85-2-401.

District Court supervision of water distribution, 85-2-406.

85-5-106. Maintenance and repair of ditches or systems. Upon written request of the owners of at least 51% of the water rights in any adjudicated ditch or single water system, the judge of the district court may empower the commissioner to maintain and keep in reasonable repair such water ditch or water system at the expense of the owners thereof, and for such purposes the commissioner shall have authority to enter and work upon any ditch, canal, aqueduct, or other source of conveying the waters affected by the decree and the right-of-way thereof and to visit, inspect, and adjust all headgates or other means of distribution of such waters.

History: En. Sec. 6, Ch. 43, L. 1911; re-en. Sec. 7141, R.C.M. 1921; re-en. Sec. 7141, R.C.M. 1935; R.C.M. 1947, 89-1006.

Cross-References

Board plan for acquisition and construction, 85-7-1901.

Entry upon land by Board or agent, 85-7-1903.

85-5-107. Record of daily distribution of water. Each water commissioner must keep a dailyrecord of the amount of water distributed to each water user and must file a summary of such record with the clerk of the court monthly or seasonally, at the discretion of the district judge during his term of service, showing in detail the total amount of water distributed each day to each water user during such month or season and the amount of cost therefor, based upon the water commissioner's or commissioners' salary per day and other costs of the water commissioner approved by the district judge, and the proportionate amount of water distributed. When two or more water commissioners serve under the same decree or decrees by order of the judge, they may file a joint summary of their record with the clerk of the court, or the chief commissioner, if one has been appointed by the judge, may file a summary in behalf of all of them.

History: En. Sec. 9, Ch. 43, L. 1911; re-en. Sec. 7144, R.C.M. 1921; re-en. Sec. 7144, R.C.M. 1935; R.C.M. 1947, 89-1009; amd. Sec. 1, Ch. 305, L. 1983.

Cross-References

General duties of Clerk of District Court, 3-5-501.

Measurement of water, 85-2-103

District Court supervision of water distribution, 85-2-406

85-5-108. Authority and arrest power. For the purposes of carrying out the provisions of parts 1 through 3 of this chapter, each commissioner appointed by the court shall have authority to enter upon any ditch, canal, aqueduct, or other source for conveying the waters affected by the decree and to visit, inspect, and adjust all headgates or other means of distributing the waters and shall have the same powers as a sheriff or constable to arrest any and all persons interfering with the distribution made by him, to be dealt with according to law.

History: En. Sec. 8, Ch. 43, L. 1911; re-en. Sec. 7143, R.C.M. 1921; re-en. Sec. 7143, R.C.M. 1935; R.C.M. 1947, 89-1008.

Cross-References

Arrest, Title 46, ch. 6

Entry upon land by Board or agent, 85-7-1903.

85-5-109. Failure to perform duty as a contempt of court. If any commissioner shall fail to perform any of the duties imposed upon him by the order of the judge of the district court, he shall be deemed guilty of a contempt of said court.

History: En. Sec. 7, Ch. 43, L. 1911; re-en. Sec. 7142, R.C.M. 1921; re-en. Sec. 7142, R.C.M. 1935; R.C.M. 1947, 89-1007.

Cross-References

Contempts, Title 3, ch. 1, part 5

85-5-110. Appointment of water mediators — duties. (1) The judge of the district court may appoint a water mediator to mediate a water controversy in a decreed or nondecreed basin under the following circumstances:

(a) upon request of the governor;

(b) upon petition by at least 15% of the owners of water rights in a decreed or nondecreed basin; or

(c) in the discretion of the district court having jurisdiction.

(2) A water mediator appointed under this section may:

(a) discuss proposed solutions to a water controversy with affected water right holders;

(b) review options related to scheduling and coordinating water use with affected water right holders;

(c) discuss water use and water needs with persons and entities affected by the existing water use;

(d) meet with principal parties to mediate differences over the use of water; and

(e) hold public meetings and conferences to discuss and negotiate potential solutions to controversies over use of water.

(3) If the governor requests or a state agency petitions for a water mediator, the governor or agency shall pay all or a majority of the costs of the water mediator, as determined equitable by the district court having jurisdiction.

(4) The governor may use funds appropriated under 75-1-1101 to pay the costs of a water mediator.

(5) Nothing in this section allows a water mediator to require any valid water right holder to compromise or reduce any of his existing water rights.

(6) If an appropriator voluntarily ceases to use all or part of his appropriation right or voluntarily ceases to use his appropriation right according to its terms and conditions as a result of the efforts of a mediator appointed under this section, the appropriator may not be considered to have abandoned all or any portion of his appropriation right.

History: En. Sec. 1, Ch. 625, L. 1989; amd. Sec. 1, Ch. 108, L. 1991.

Cross-References

Environmental contingency account objectives, 75-1-1101

85-5-111. Water commissioner and mediator education. The department of natural resources and conservation, in cooperation with the Montana supreme court, the Montana water courts, the district courts of Montana, the Montana university system, and other appropriate state and federal agencies, shall develop an educational program for water commissioners and mediators that includes:

(1) an annual seminar on commissioner and mediator duties, mediation techniques, and water measuring techniques;

(2) preparation and, as necessary, revision of a water commissioner and mediator manual; and

(3) an outreach program that identifies persons who might serve as water commissioners or mediators.

History: En. Sec. 2, Ch. 625, L. 1989.

Part 2

Charges and Expenses

85-5-201. Distribution of water and related expenses. Every water commissioner appointed by the judge of the district court for that purpose shall have the authority to admeasure and distribute to the parties interested, under such decree, permit, or certificate, the water to which those who are parties to the decree or holders of a permit or certificate, or privy thereto, are entitled, according to their priority as established by the decree, permit, or certificate. The water commissioner, in case the parties fail or refuse to do so, may incur necessary expenses in the making of headgates or dams for the distribution of the waters. Such expense shall be assessed against and paid by the party or parties for whom such services in the repair of the ditch or ditches and the making of any dams or headgates were necessary. In the discretion of the court, such costs or expenses may be assessed against the land upon which or for the benefit of which such expense had been incurred.

History: En. Sec. 5, Ch. 43, L. 1911; re-en. Sec. 7140, R.C.M. 1921; amd. Sec. 2, Ch. 125, L. 1925; re-en. Sec. 7140, R.C.M. 1935; R.C.M. 1947, 89-1005; amd. Sec. 2, Ch. 246, L. 1983.

Cross-References

Appointment of Water Commissioners, 3-7-211, 85-5-101

Priority, 85-2-401

Irrigation districts — indebtedness, bonds, and bankruptcy, Title 85, ch. 7, part 20

Irrigation districts — taxes and assessments, Title 85, ch. 7, part 21

85-5-202. Repair expenses. The judge may also allow as a charge any expenses necessarily incurred by the water commissioner in the discharge of his duties in the employment of extra labor for the repair of dams, headgates, ditches, or flumes when immediate action is necessary to preserve the rights of the parties entitled to the waters of such stream or when the judge has, in the order appointing the commissioner, required the commissioner to repair ditches and keep in repair necessary headgates, ditches, or flumes. The water commissioner shall report all such expenses, and the cost thereof shall be taxed against the party or parties for whose

benefit the same were incurred. In the discretion of the court, such costs or expenses may be assessed against the land upon which or for the benefit of which such expense had been incurred.

History: En. Sec. 10, Ch. 43, L. 1911; re-en. Sec. 7145, R.C.M. 1921; amd. Sec. 3, Ch. 125, L. 1925; re-en. Sec. 7145, R.C.M. 1935; R.C.M. 1947, 89-1010.

Cross-References

Board powers over district property, 85-7-1908.

85-5-203. Telephone expenses. The judge may also allow as a charge reasonable expenses incurred by a water commissioner in telephoning to the judge for instructions in cases of emergency. When there are two or more commissioners acting under the judge's order, reasonable expenses incurred in communicating with each by telephone or with the judge of the district court, in order to carry on the distribution of the waters harmoniously and in accordance with the decree, shall be deemed a necessary expense. These expenses shall be reported by the water commissioner or commissioners at the close of the season and shall be taxed against all the water users affected by the decree or decrees ratably in proportion to the whole amount of water distributed to them during the season.

History: En. Sec. 11, Ch. 43, L. 1911; re-en. Sec. 7146, R.C.M. 1921; re-en. Sec. 7146, R.C.M. 1935; R.C.M. 1947, 89-1011.

Cross-References

Water Judges, Title 3, ch. 7, part 2.

85-5-204. Apportionment of fees and expenses. (1) Upon the filing of the report by the water commissioner or water commissioners, the clerk of court shall forthwith notify by letter each person mentioned in such report:

(a) of the amount he is made liable for by such report;

(b) that objections to such report and the amount so taxed against him may be made by any person interested therein within 20 days after the date of the mailing of said notice; and

(c) unless objections thereto are filed, an order will be made by the judge of said court finally fixing and determining the amount due from each of said water users.

(2) The affidavit of the clerk that he has mailed a notice to each person mentioned in the report at such person's last known post-office address, in the usual manner, shall be deemed prima facie evidence that the person received that notice provided for in this section.

History: En. Sec. 12, Ch. 43, L. 1911; re-en. Sec. 7147, R.C.M. 1921; amd. Sec. 1, Ch. 11, L. 1923; amd. Sec. 1, Ch. 45, L. 1927; re-en. Sec. 7147, R.C.M. 1935; R.C.M. 1947, 89-1012.

Cross-References

General duties of Clerk of District Court, 3-5-501.

85-5-205. Objections to expenses — hearing. At the expiration of the 20 days' notice, as provided for in the preceding section, if objections to said report have been filed or a motion to retax the same has been made, the court or judge shall fix a time for the hearing of such objections or motion to retax, which time of hearing shall be as soon as the judge or a court can conveniently hear the same. Any person objecting to said report shall be entitled to at least 5 days' notice of the date and time of such hearing. At such hearing the court or judge shall hear and determine the motion or objections and shall make an order fixing and determining the amount found due from each of said water users to such commissioner or commissioners. In case no objections are filed within the 20 days, as hereinbefore provided for, such order shall be made as a matter of course, and in either case said order shall be final determination of the matter.

History: En. Sec. 13, Ch. 43, L. 1911; re-en. Sec. 7148, R.C.M. 1921; amd. Sec. 2, Ch. 11, L. 1923; re-en. Sec. 7148, R.C.M. 1935; R.C.M. 1947, 89-1013.

85-5-206. Effect of order fixing fees. After the order of the court fixing the fees and compensation and expenses of the water commissioner is final, it shall have all the force and effect of a judgment as against the person to whom the water was admeasured and for whose benefit it was used. When such expense of commissioner or commissioners has been assessed against the land for which such service of the commissioner or commissioners has been rendered, it shall constitute a lien against said land. Execution may issue upon the order, as upon a judgment, by direction of the court or judge upon the application of any person interested therein. The water commissioner, at his discretion, may withhold further admeasurement or distribution of water to any person otherwise entitled thereto until such person shall have paid all fees, compensation, and expenses of such water commissioner or commissioners so fixed by the court and apportioned and charged to such person and likewise may withhold the admeasurement and distribution of water from any land against which there exists any such lien as aforesaid, until such lien shall have been fully discharged.

History: En. Sec. 14, Ch. 43, L. 1911; re-en. Sec. 7149, R.C.M. 1921; amd. Sec. 4, Ch. 125, L. 1925; amd. Sec. 1, Ch. 39, L. 1929; re-en. Sec. 7149, R.C.M. 1935; R.C.M. 1947, 89-1014.

Cross-References

Appointment of Water Commissioners, 3-7-211, 85-5-101

Execution of judgment, Title 25, ch. 13

District Court supervision of water distribution, 85-2-406

Part 3

Rights and Duties of Water Users

85-5-301. Complaint by dissatisfied user. (1) A person owning or using any of the waters of the stream or ditch or extension of the ditch who is dissatisfied with the method of distribution of the waters of the stream or ditch by the water commissioner or water commissioners and who
claims to be entitled to more water than he is receiving or to a right prior to that allowed him by the water commissioner or water commissioners may file his written complaint, duly verified, setting forth the facts of the claim. Thereupon the judge shall fix a time for the hearing of such petition and shall direct that such notice be given to the parties interested in the hearing as the judge considers necessary. At the time fixed for the hearing, the judge must hear and examine the complainant and other parties as may appear to support or resist such claim and examine the water commissioner or water commissioners and witnesses as to the charges contained in the complaint.

(2) Upon the determination of the hearing, the judge shall make such findings and order as he considers just and proper. If it appears to the judge that the water commissioner or water commissioners have not properly distributed the water according to the provisions of the decree, the judge shall give the proper instructions for such distribution. The judge may remove any water commissioner and appoint some other person in his stead if he considers that the interests of the parties in the waters mentioned in the decree will be best subserved thereby, and if it appears to the judge that the water commissioner has willfully failed to perform his duties, he may be proceeded against for contempt of court, as provided in contempt cases. The judge shall make such order as to the payment of costs of the hearing as appears to him to be just and proper.

History: En. Sec. 15, Ch. 43, L. 1911; re-en. Sec. 7150, R.C.M. 1921; amd. Sec. 5, Ch. 125, L. 1925; re-en. Sec. 7150, R.C.M. 1935; amd. Sec. 13, Ch. 460, L. 1977; R.C.M. 1947, 89-1015.

Cross-References

Contempts, Title 3, ch 1, part 5

Appeals from final decree, 85-2-235.

85-5-302. Maintenance of headgates and measuring devices. All persons using water from any stream or ditch whereon a water commissioner is appointed are required to have suitable headgates at the point where a ditch taps a stream and shall also, at some suitable place on the ditch and as near the head as practicable, place and maintain a proper measuring box, weir, or other appliance for the measurement of the waters flowing in the ditch. In case any person or persons shall fail to place or maintain a proper measuring appliance, it is the duty of the water commissioner not to apportion or distribute any water through the ditch. The commissioner shall notify all parties interested by certified mail or in

person 1 week before making the annual repair or cleaning of any stream or ditch or performing necessary labor or expenses to divert water to any ditch. The sending of a certified letter to the last-known post-office address of any interested party is prima facie evidence of the fact that he was duly notified. Any work in the way of repairing a ditch made necessary by any emergency may be done without such notice when injury would result from delay.

History: En. Sec. 7, Ch. 64, L. 1905; re-en. Sec. 4890, Rev. C. 1907; re-en. Sec. 7151, R.C.M. 1921; amd. Sec. 6, Ch. 125, L. 1925; re-en. Sec. 7151, R.C.M. 1935; R.C.M. 1947, 89-1016; amd. Sec. 4, Ch. 432, L. 1989.

Cross-References

Measurement of water, 85-2-103.
District Court supervision of water distribution, 85-2-406.
Conduction of water, 85-2-414.
Regulation, supervision, apportionment, and control of water distribution, 85-7-1922.

Part 4

Water Ditches Under Joint or Corporate Control

85-5-401. Determination of water rights between partners, tenants in common, and corporate stockholders. Whenever a water ditch used for irrigating purposes is owned by a partnership, tenants in common, or corporation and there is any dispute between the respective owners, tenants in common, or stockholders respecting the use and division of the waters flowing in said ditch, any partner, tenant in common, or stockholder may commence an action in any court of competent jurisdiction to determine the rights of the respective parties to the use of said waters and may join in his petition a prayer for the appointment of a water commissioner to apportion and distribute the waters of said ditch according to the rights of the respective owners, tenants in common, or stockholders during the pendency of the action.

History: En. Sec. 1, Ch. 181, L. 1919; re-en. Sec. 7152, R.C.M. 1921; re-en. Sec. 7152, R.C.M. 1935; R.C.M. 1947, 89-1017.

Cross-References

Appointment of Water Commissioners, 3-7-211, 85-5-101.
Water Courts — jurisdiction, Title 3, ch. 7, part 5.
District Court supervision of water distribution, 85-2-406.
Duty of purchaser to dig ditches, 85-2-416.
Board agreements for joint operation or cooperation, 85-7-1905.

85-5-402. Appointment of commissioner prior to final decree. After the filing of the complaint in such action, the court may, upon 5 days' notice to the other parties to the action, appoint a commissioner to divide and distribute the waters of said ditch to the respective parties, according

to their respective rights, during the pendency of the action. The court may, upon good cause shown, appoint such commissioner without notice, and when such commissioner is appointed without notice, any party to the action may, on 5 days' notice to the plaintiff, move the court or judge to vacate such appointment or to modify the order as to the distribution of the waters of said ditch. The court or judge on such hearing, in his discretion, may affirm, vacate, or modify the order previously made. Each water commissioner so appointed shall subscribe to an oath of office before commencing the discharge of his duties.

History: Ap. p. Sec. 2, Ch. 181, L. 1919; re-en. Sec. 7153, R.C.M. 1921; re-en. Sec. 7153, R.C.M. 1935; Sec. 89-1018, R.C.M. 1947; Ap. p. Sec. 3, Ch. 181, L. 1919; re-en. Sec. 7154, R.C.M. 1921; re-en. Sec. 7154, R.C.M. 1935; Sec. 89-1019, R.C.M. 1947; R.C.M. 1947, 89-1018, 89-1019(part).

Cross-References

Appointment of Water Commissioners, 3-7-211, 85-5-101.

Final decree, 85-2-234.

85-5-403. Division of water. It shall be the duty of the water commissioner to divide the waters of said ditch between the owners, tenants in common, or stockholders in proportion to their respective rights, as set forth in the complaint or in such other manner or proportion as the court or judge may direct.

History: En. Sec. 3, Ch. 181, L. 1919; re-en. Sec. 7154, R.C.M. 1921; re-en. Sec. 7154, R.C.M. 1935; R.C.M. 1947, 89-1019(part).

Cross-References

District Court supervision of water distribution, 85-2-406.

85-5-404. Authority of commissioner. Such commissioner shall have authority to enter upon said ditch; open, close, and set headgates; and do whatever else is necessary to apportion and distribute the waters of said ditch to the respective parties according to their respective rights.

History: En. Sec. 4, Ch. 181, L. 1919; re-en. Sec. 7155, R.C.M. 1921; re-en. Sec. 7155, R.C.M. 1935; R.C.M. 1947, 89-1020.

Cross-References

Entry upon land by Board or agent, 85-7-1903.

85-5-405. Compensation and expenses. The court shall fix the compensation of such commissioner and the term of his employment and shall make an order apportioning the amount of such compensation among the several owners, tenants in common, or stockholders of said ditch, according to their respective rights and interest in said ditch, which amounts so apportioned shall be taxed as costs in the action against the respective parties.

History: En. Sec. 5, Ch. 181, L. 1919; re-en. Sec. 7156, R.C.M. 1921; re-en. Sec. 7156, R.C.M. 1935; R.C.M. 1947, 89-1021.

Cross-References

Appointment of Water Commissioners, 3-7-211, 85-5-101

85-5-406. Interference with actions of commissioner. Any person opening or closing a headgate after being set by such commissioner or who in any manner interferes with such commissioner in the discharge of his duties shall be deemed guilty of contempt of court and may be proceeded against for contempt of court as provided in contempt cases.

History: En. Sec. 6, Ch. 181, L. 1919; re-en. Sec. 7157, R.C.M. 1921; re-en. Sec. 7157, R.C.M. 1935; R.C.M. 1947, 89-1022.

Cross-References

Contempts, Title 3, ch. 1, part 5.

85-5-407. Appointment of water commissioner after final decree. When the rights of the respective parties in an action to the use of the waters flowing in a ditch are adjudicated, the judge of the district court having jurisdiction of the subject matter, upon the application of the owners of at least 10% of the waters of the ditch, may, in the exercise of the judge's discretion, appoint a water commissioner to divide, apportion, and distribute the waters of the ditch to the respective parties according to their respective rights as set forth in the decree. When a commissioner is appointed under the provisions of this chapter to apportion and distribute the waters of the stream from which the water flowing in a ditch is taken, the commissioner shall, when directed by the judge or court, apportion and distribute the waters of the ditch according to the decree by which the rights of the respective owners were adjudicated.

History: En. Sec. 7, Ch. 181, L. 1919; re-en. Sec. 7158, R.C.M. 1921; re-en. Sec. 7158, R.C.M. 1935; R.C.M. 1947, 89-1023; amd. Sec. 301, Ch. 42, L. 1997.

Cross-References

Appointment of Water Commissioners, 3-7-211.

Appeals from final decree, 85-2-235.

85-5-408. Apportionment of costs. (1) When a commissioner is appointed upon the application of an owner or owners of a ditch, the court may fix the compensation of the commissioner and the term of the commissioner's employment. The court shall make an order apportioning the amount of compensation among the several owner or owners, tenants in common, or stockholders of the ditch according to their respective rights and interest. The order has the effect of a judgment against the person to whom the water was admeasured and for whose benefit it was used. When, in the discretion of the court, an order of apportionment of expense is made against the land for which the water was used, it has the effect of a lien against the land to which the apportionment was made. Execution may issue upon the order as upon a judgment by direction of the court, upon the application of any person interested in the order.

(2) When a commissioner is appointed under the provisions of this chapter to distribute the waters of the stream from which the waters flowing

in a ditch are taken and to apportion and distribute the waters of the ditch according to the rights of the respective owners of the waters, the judge, in the judge's discretion, may, in addition to the apportionment taxed against the respective owners of the waters of the stream, apportion and tax the amount, if any, that the owners of the ditch shall pay in addition to the amount taxed under the provisions of this chapter.

History: En. Sec. 8, Ch. 181, L. 1919; re-en. Sec. 7159, R.C.M. 1921; amd. Sec. 7, Ch. 125, L. 1925; re-en. Sec. 7159, R.C.M. 1935; R.C.M. 1947, 89-1024; amd. Sec. 302, Ch. 42, L. 1997.

Cross-References

Execution of judgment, Title 25, ch. 13.
Apportionment of fees and expenses, 85-5-204.
Irrigation districts — taxes and assessments, Title 85, ch. 7, part 21.

SAMPLE INSTRUCTIONS TO WATER COMMISSIONERS

IN THE DISTRICT COURT OF THE FOURTH JUDICIAL DISTRICT OF THE STATE OF MONTANA, IN AND FOR THE COUNTY OF RAVALLI

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1. After the water commissioner has been appointed and has furnished the necessary bond, the water commissioner must notify all persons who will be receiving water of the appointment. The water commissioner must also take down the name and address of each person, the amount of water he or she claims to be entitled to receive, the mailing address, and, if possible, the phone number. The water commissioner must deliver this information to the clerk of court as soon as possible.

2. The water commissioner must furnish to each water user a phone number, address, and the hours when the water commissioner can be reached regarding the handling of the decreed water.

3. The water commissioner must study the "Instructions for a Water Commissioner" prepared by the court and follow them. The commissioner should also study all the information available to the clerk of court regarding the water rights and the distribution system.

4. If the clerk does not have some type of map of the watershed showing the location of all ditches and the places where they take water from the stream, then it shall be the duty of the water commissioner to prepare such a map. The map need not be such as a surveyor would prepare, but should be complete enough to enable the court to understand the distribution system and locate the ditches if necessary.

5. When a problem arises and the water commissioner cannot find the answer in any of the instructions, a court hearing may be necessary. However, Section 85-5-203 of the Montana Code permits a water commissioner to use the telephone and call the judge for instructions.

6. The water commissioner must make the reports regarding the distribution of water required by law. Otherwise, payment for services cannot be expected.

7. Many watersheds have lakes where irrigation water is stored. Most of that water is not part of a decree. Therefore, special rules apply, and the time expended in working with the lake water is to be charged against the lake water users and not the decreed water users. Normally the clerk of court does not handle that part of the collection process.

SAMPLE

WARNING

THIS DIVERSION HAS BEEN REGULATED BY THE FOURTH JUDICIAL DISTRICT COURT WATER COMMISSIONER

DISTRICT CHIEF COMMISSIONER

WATER COMMISSIONER

TAMPERING WITH WATER SETTINGS MAY RESULT IN A CHARGE OF CONTEMPT OF COURT

Section 85-5-108 M.C.A.

ALLOCATION REPORT

DRAINAGE _____ COUNTY _____

DECREE CAUSE NO. _____ DECREE DATE _____

REPORTING MONTH _____

DITCH NAME	MONTHLY TOTAL IN MINER'S INCHES	COST PER INCH AMOUNT DUE	DATE FILED	DATE RECEIVED

SIGNED _____

WATER COMMISSIONER

COMMISSIONER BILLING REPORT

DITCH NAME OR USER NAME	SERVICES PERFORMED COMM. LOG DATE	TIME	COST	DATE MAILED	DATE RECEIVED

DNRC INFORMATION

DNRC INFORMATION

Information on water and related resources, water rights, measuring devices, and water law can be obtained from the DNRC Water Resources Regional Offices. Photographs, maps, and reference works may also be available; samples are included of those items marked with an asterisk.

- Aerial photographs

- Topographic maps by the U.S. Geological Survey

- Water Resources Surveys (by county) done by the State Engineer's Office*

    - The information in these surveys consists of maps, field notes, and decree indexes.

- U.S. Geological Survey stream gauging data*

- Water rights indexes by drainage*

    - Source name by priority date
    - Owner Name
    - Point of diversion
    - Water right number
    - Place of use (only on microfiche)

- Water measuring assistance

    - Check of measuring devices
    - Advice on placement

- Microfiche of existing water rights as claimed and as decreed; microfiche of permitted rights*

- Administration of permitted water rights; changes to existing rights

- General information on Montana Water Law

Water Resources Survey

Part I:

HISTORY OF LAND AND WATER USE ON IRRIGATED AREAS

and

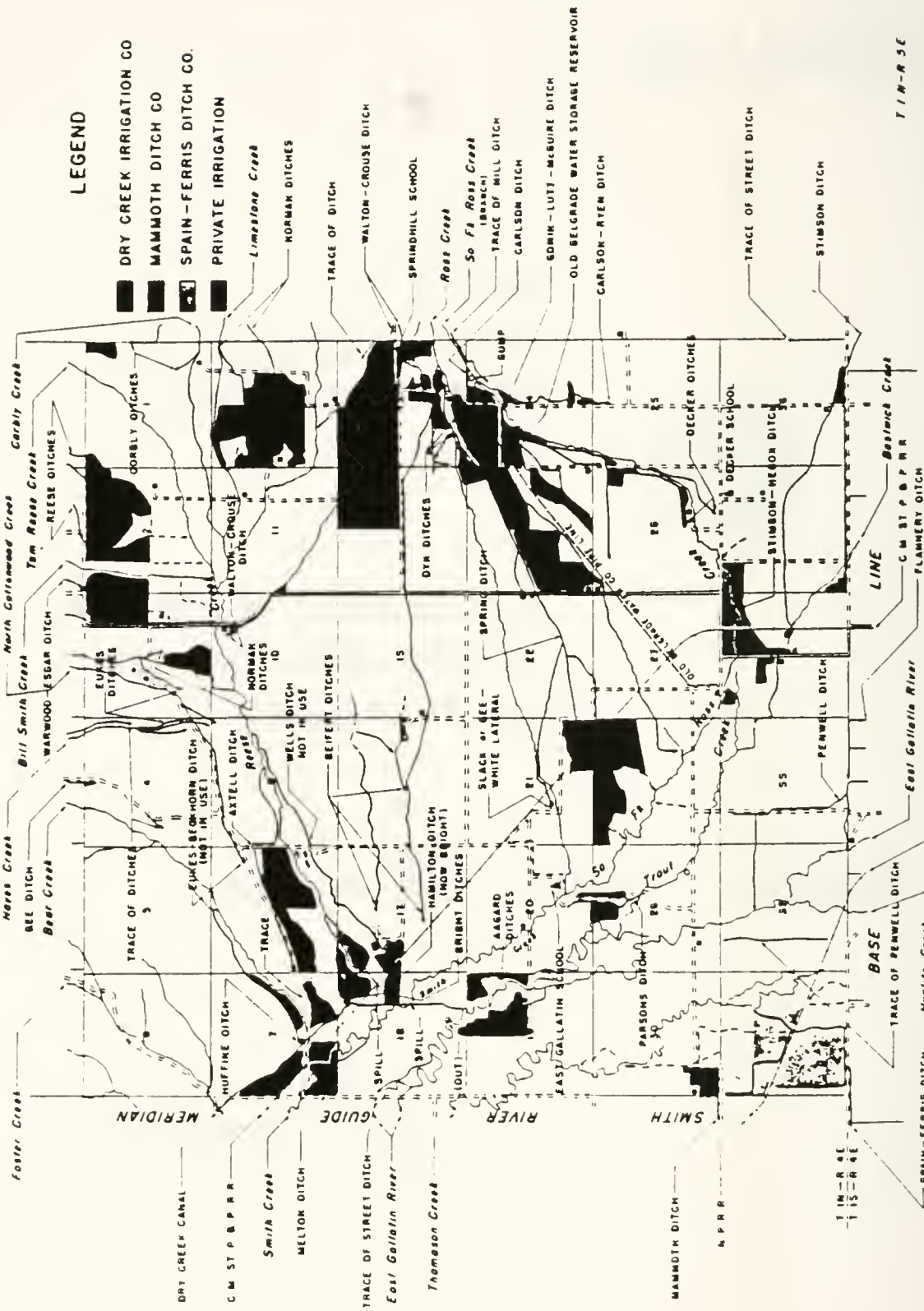
Part II:

MAPS SHOWING IRRIGATED AREAS IN COLORS DESIGNATING THE SOURCES OF SUPPLY

Gallatin County, Montana

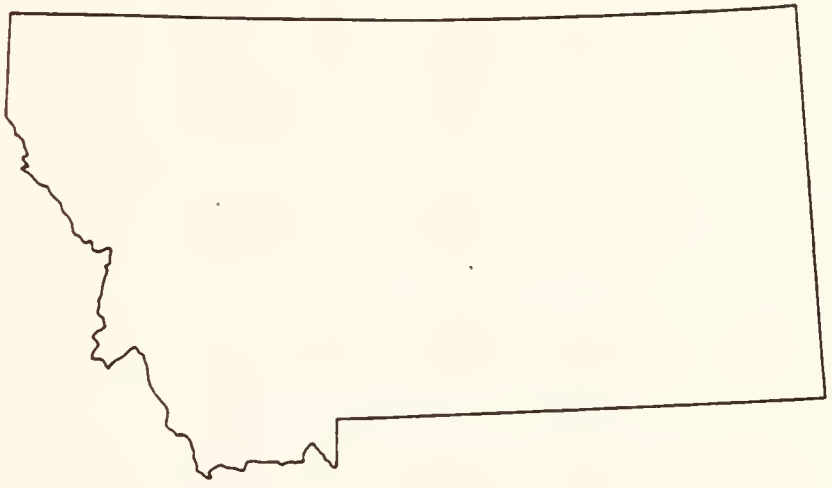
Published by
STATE ENGINEER'S OFFICE
Helena, Montana, January, 1953
(Reprint as of June, 1961)

Map from Water Resources Survey indicating irrigated acreage and ditches.



Water Resources Data Montana Water Year 1992

by R.R. Shields, J.R. Knapton, M.K. White, T.M. Brosten, and C.L. Chambers



U.S. GEOLOGICAL SURVEY WATER-DATA REPORT MT-92-1
Prepared in cooperation with the State of Montana
and with other agencies

12329500 FLINT CREEK AT MAXVILLE, MT

LOCATION.--Lat 46°27'50", long 113°14'20", in NE1/4SW1/4NW1/4 sec.9, T.8 N., R.13 W., Granite County, Hydrologic Unit 17010202, on right bank 0.4 mi west of Maxville and 1.0 mi upstream from Boulder Creek.
DRAINAGE AREA.--208 mi^2.

WATER-DISCHARGE RECORDS

PERIOD OF RECORD.--August 1941 to current year. April 1939 to September 1941 at site 0.5 mi upstream; records not equivalent owing to diversions.
REVISED RECORDS.--WSP 1216: Drainage area.
GAGE.--Water-stage recorder. Datum of gage is 4,828.38 ft above National Geodetic Vertical Datum of 1929.
REMARKS.--Estimated daily discharges: Oct. 28 to Nov. 6, Nov. 22-24, Nov. 29 to Dec. 4, Dec. 14 to Jan. 3, Jan. 14-21, Feb. 3-8, 17, 18. Water-discharge records good except those for estimated daily discharges, which are poor. Several observations of water temperature and specific conductance were made during the year. Some regulation by Georgetown Lake (station number 12325000). Diversions for irrigation of about 8,200 acres upstream from station. During irrigation season, flow is supplemented by water from East Fork Rock Creek which is diverted in sec.5, T.4 N., R.14 W., 500 ft below Rock Creek Dam, through a canal into Trout Creek, thence into Flint Creek.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1991 TO SEPTEMBER 1992
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	64	e32	e38	e32	60	63	63	56	121	74	46	24
2	64	e30	e40	e33	57	64	62	48	110	75	44	26
3	65	e32	e42	e36	e54	65	62	43	102	76	42	26
4	63	e40	e46	35	e52	67	70	41	99	67	41	27
5	60	e50	50	38	e50	68	72	38	90	67	40	26
6	59	e54	58	36	e50	65	65	37	94	64	39	27
7	58	54	65	40	e50	64	62	34	92	64	37	28
8	59	55	52	39	e52	63	65	34	88	66	35	30
9	57	55	51	38	54	60	64	30	81	62	35	31
10	56	53	47	43	54	60	65	30	83	61	32	30
11	53	51	47	45	55	61	63	25	86	63	30	30
12	51	53	52	49	55	62	62	23	123	66	27	33
13	49	58	50	46	56	62	62	22	120	60	22	34
14	48	55	e45	e44	57	62	63	24	124	56	17	34
15	48	49	e40	e40	57	62	64	39	98	53	20	37
16	47	47	e33	e40	58	74	65	46	88	52	24	37
17	47	52	e30	e36	e56	80	72	59	111	49	23	35
18	46	51	e28	e34	e54	76	76	63	84	47	23	34
19	47	50	e28	e36	59	74	71	72	69	47	22	35
20	46	50	e26	e32	74	73	68	75	59	56	27	36
21	46	50	e28	e34	76	68	60	91	55	58	28	37
22	47	e46	e30	35	64	66	61	86	53	64	27	37
23	45	e44	e32	42	62	65	59	84	65	66	30	37
24	45	e50	e32	53	60	64	56	88	71	62	32	40
25	45	53	e32	52	59	64	54	95	71	58	30	42
26	47	52	e30	49	61	63	53	96	72	55	28	40
27	48	51	e30	48	63	65	52	110	65	53	30	39
28	e40	49	e30	53	63	64	54	111	66	49	29	38
29	e37	e40	e32	57	63	62	53	124	68	49	25	39
30	e34	e36	e32	57	---	62	60	147	77	48	24	38
31	e34	---	e32	58	---	62	---	131	---	47	24	---
TOTAL	1555	1442	1208	1310	1685	2030	1878	2002	2585	1834	933	1007
MEAN	50.2	48.1	39.0	42.3	58.1	65.5	62.6	64.6	86.2	59.2	30.1	33.6
MAX	65	58	65	58	76	80	76	147	124	76	46	42
MIN	34	30	26	32	50	60	52	22	53	47	17	24
AC-FT	3080	2860	2400	2600	3340	4030	3730	3970	5130	3640	1850	2000

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1942 - 1992, BY WATER YEAR (WY)

MEAN	86.0	73.5	61.4	54.3	61.2	75.5	108	140	188	126	106	92.7
MAX	148	121	120	88.1	116	186	310	353	455	324	217	147
(WY)	1976	1984	1976	1976	1968	1943	1948	1976	1948	1975	1975	1978
MIN	50.2	43.9	33.4	27.0	28.9	33.5	48.6	64.6	70.7	48.1	30.1	33.6
(WY)	1992	1962	1962	1955	1955	1955	1961	1992	1987	1973	1992	1992

SUMMARY STATISTICS	FOR 1991 CALENDAR YEAR		FOR 1992 WATER YEAR		WATER YEARS 1942 - 1992	
ANNUAL TOTAL	22737		19469			
ANNUAL MEAN	62.3		53.2		97.8	
HIGHEST ANNUAL MEAN					165	1976
LOWEST ANNUAL MEAN					53.2	1992
HIGHEST DAILY MEAN	204	Jun 7	147	May 30	933	Mar 29 1943
LOWEST DAILY MEAN	25	Jan 29	17	Aug 14	15	Feb 25 1962
ANNUAL SEVEN-DAY MINIMUM	27	Jan 23	22	Aug 13	19	Dec 31 1957
INSTANTANEOUS PEAK FLOW			159a	May 30	1680c	Mar 28 1943
INSTANTANEOUS PEAK STAGE			3.39b	Feb 6	8.08b	Feb 4 1963
ANNUAL RUNOFF (AC-FT)	45100		38620		70850	
10 PERCENT EXCEEDS	104		75		168	
50 PERCENT EXCEEDS	53		52		80	
90 PERCENT EXCEEDS	34		30		45	

a--Gage height, 3.06 ft.
b--Backwater from ice.
c--Gage height, 6.79 ft.
e--Estimated.

NOTE: * - VERIFIED WATER RIGHT, G - GALLONS/MIN C - CUBIC FEET/SEC, X - UNNAMED TRIBUTARY TO SOURCE, & - ONLY FIRST POD LISTED

WATER RIGHT ID	USE	FLOW RATE		PRIORITY DATE	POINT OF DIVERSION QTR	SEC	SEC	TWP	RGE	CN	UT	SOURCE NAME	OWNER NAME
41A -W-052982-00	ST	4.49	G	11/05/1906	SWSESW	24	14S	10W	BE			ADOBE SPRING	USA (DEPT OF AGRICULTURE FOREST
41A -W-095131-00	IR	20.00	C	08/03/1900	NWSWSE	10	13S	09W	BE			AL YOUNG SPRING	MARTINELL, LEE CO
41A -W-052788-00	ST	4.49	G	11/05/1906	NWNWNE	9	15S	08W	BE			ALDER CREEK	USA (DEPT OF AGRICULTURE FOREST
41A -W-052796-00	ST	.10	C	11/05/1906	NENENW	9	15S	08W	BE			ALDER CREEK SPRING	USA (DEPT OF AGRICULTURE FOREST
41A -W-094644-00	IR	4.38	C	05/12/1887	SWSWSE	3	14S	08W	BE			ALDERDICE	IDAHO, STATE OF DIXON W DEAN
41A -W-094634-00	IR	12.50	C	04/20/1888	SWSWSE	3	14S	08W	BE			ALDERDICE	IDAHO, STATE OF DIXON W DEAN
41A -W-094643-00	IR	2.00	C	04/20/1888	SWSWSE	3	14S	08W	BE			ALDERDICE	IDAHO, STATE OF DIXON W DEAN
41A -W-094645-00	ST	1,000.00	G	05/12/1887	SW	3	14S	08W	BE&			ALDERDICE SPRING	IDAHO, STATE OF DIXON W DEAN
41A -W-094636-00	IR	12.50	C	05/22/1885	SESWSW	3	14S	08W	BE			ALDERDICE SPRING CREEK	IDAHO, STATE OF DIXON W DEAN
41A -W-094500-00	ST	1.25	C	07/15/1889	SWNESW	16	14S	11W	BE			ALICE SPRING	HILDRETH EUGENE HILDRETH RHONDA HILDRETH CRAIG
41A -W-094472-00	IR	.50	C	06/01/1888	SESWSW	34	09S	13W	BE			ALKALI CREEK	BARRETT RANCH INC
41A -W-094473-00	IR	1.00	C	10/11/1902	SESWSW	34	09S	13W	BE			ALKALI CREEK	BARRETT RANCH INC
41A -W-137085-00	ST			02/23/1929	N2S2	1	15S	11W	BE			ALKALI CREEK	USA (DEPT OF INTERIOR BUREAU OF
41A -W-052899-00	ST	4.49	G	11/05/1906	SENENE	18	15S	11W	BE			ALKALI CREEK, NORTH FORK	USA (DEPT OF AGRICULTURE FOREST
41A -W-137091-00	ST			02/28/1932	N2NW	17	15S	11W	BE			ALKALI CREEK, NORTH FORK	MONTANA, STATE OF BOARD OF LAND
41A -W-052900-00	ST	4.49	G	11/05/1906	NENENE	20	15S	11W	BE			ALKALI CREEK, SOUTH FORK	USA (DEPT OF AGRICULTURE FOREST
41A -W-137092-00	ST			06/14/1919	W2	16	15S	11W	BE			ALKALI CREEK, SOUTH FORK	MONTANA, STATE OF BOARD OF LAND
41A -P-013398-00	ST	10.00	G	06/14/1977	NESESW	17	15S	11W	BE			ALKALI CREEK, SOUTH FORK	USA (DEPT OF INTERIOR BUREAU OF
41A -W-095335-00	ST	.50	C	03/00/1889	SWSWSE	8	15S	11W	BE			ALKALI SPRINGS	SAN FELIPE RANCH INC
41A -W-094991-00	IR	9.00	C	05/26/1899	NESWNE	28	14S	04W	BE			ALKALIE FLAT	MATADOR CATTLE CO

NOTE: * - VERIFIED WATER RIGHT, G - GALLONS/MIN C - CUBIC FEET/SEC, X - UNNAMED TRIBUTARY TO SOURCE, & - ONLY FIRST POD LISTED

WATER RIGHT	USE	RATE	VOLUME	. POINT OF DIVERSION . QIR	SCTN	SC	TWP	RGE	CN	UT	SOURCE NAME	OWNER NAME
S41A W094435-00	IR	8.00 C	2,640.00	NESWNE	14	14S	01E	BE			RED ROCK CREEK, NORTH BRANCH	ALASKA BASIN GRAZING ASSOC
S41A W094436-00	IR	4.00 C	1,320.00	SESESW	15	14S	01E	BE			HORSE CAMP CREEK	ALASKA BASIN GRAZING ASSOC
S41A W094437-00	IR	3.00 C	990.00	NENENW	15	14S	01E	BE			RED ROCK CREEK	ALASKA BASIN GRAZING ASSOC
S41A W094438-00	IR	7.00 C	2,310.00	NWNENW	15	15S	01E	BE			RED ROCK CREEK	ALASKA BASIN GRAZING ASSOC
S41A W094439-00	IR	2.50 C	825.00	SESENE	15	14S	01E	BE			RED ROCK CREEK	ALASKA BASIN GRAZING ASSOC
S41A W094440-00	IR	1.25 C	412.50	NWNENW	22	14S	01E	BE			HORSE CAMP CREEK	ALASKA BASIN GRAZING ASSOC
S41A W094441-00	IR	6.00 C	2,100.00	SWSWSW	24	14S	01E	BE			HELLROARING CREEK	ALASKA BASIN GRAZING ASSOC
S41A W094442-00	IR	4.00 C	1,320.00	NESWNE	14	14S	01E	BE			RED ROCK CREEK	ALASKA BASIN GRAZING ASSOC
G41A C062178-00	CM	22.00 G	10.08	NESW	12	12S	10W	BE			WELL	AMOCO PRODUCTION CO
G41A C087873-00	DM	10.00 G	1.73	SWSE	30	13S	08W	BE			WELL	ANDERSEN PETER E
G41A W132584-00	ST	20.00 G	2.50	SWSWNE	5	13S	02W	BE			GAYUSE	ANDERSON JOHN H
S41A W095284-00	IR	4.00 C	1,560.00	SWSWSW	27	11S	14W	BE			NIP & TUCK	ARTHUR, J INC
S41A W049613-00	ST	5.00 C	2,250.00	E2SW	26	08S	13W	BE&			WATSON CREEK	BANNACK GRAZING ASSOC
G41A C067534-00	LG	6.00 G	6.92	NWNWSW	24	10S	15W	BE			WELL (DEPTH - 165 FT)	BAR DOUBLE T RANCH INC
S41A W103161-00	IR	2.00 C	600.00	SENESE	25	10S	15W	BE&			BEAR CREEK	BAR DOUBLE T RANCH INC
S41A W103162-00	IR	5.00 C	1,500.00	SENESE	25	10S	15W	BE&			BEAR CREEK	BAR DOUBLE T RANCH INC
S41A W103163-00	IR	.85 C	255.00	SENESE	25	10S	15W	BE&			BEAR CREEK	BAR DOUBLE T RANCH INC
S41A W103164-00	IR	1.35 C	405.00	SENESE	25	10S	15W	BE&			BEAR CREEK	BAR DOUBLE T RANCH INC
S41A W103165-00	IR	1.25 C	375.00	SENESE	25	10S	15W	BE&			BEAR CREEK	BAR DOUBLE T RANCH INC
S41A W111801-00	IR	5.00 C	1,500.00	NWNENW	20	10S	14W	BE			TRAIL CREEK	BAR DOUBLE T RANCH INC
S41A W111802-00	IR	4.00 C	1,200.00	NENESW	22	10S	15W	BE&			FRY PAN CREEK	BAR DOUBLE T RANCH INC
S41A W111803-00	IR	1.00 C	300.00	SWNWSW	14	10S	15W	BE&			TRAIL CREEK	BAR DOUBLE T RANCH INC
S41A W111804-00	IR	2.63 C	887.00	NENESW	22	10S	15W	BE&			FRY PAN CREEK	BAR DOUBLE T RANCH INC
S41A W111805-00	IR	5.38 C	1,612.00	NENESW	22	10S	15W	BE&			FRY PAN CREEK	BAR DOUBLE T RANCH INC
S41A W111806-00	IR	1.25 C	375.00	SWNWSE	23	10S	15W	BE&			FRY PAN CREEK, LEFT FORK	BAR DOUBLE T RANCH INC
S41A W111807-00	IR	1.25 C	375.00	NWSWNE	27	10S	15W	BE&			FRY PAN CREEK, LEFT FORK	BAR DOUBLE T RANCH INC
S41A W111808-00	IR	2.50 C	750.00	NENESW	22	10S	15W	BE&			FRY PAN CREEK	BAR DOUBLE T RANCH INC
S41A W111809-00	IR	1.00 C	300.00	SWNWSW	14	10S	15W	BE&			TRAIL CREEK	BAR DOUBLE T RANCH INC
S41A W111810-00	IR	1.25 C	375.00	SENWSW	13	10S	15W	BE&			SHESER CREEK	BAR DOUBLE T RANCH INC
S41A W094453-00	IR	.95 C	342.00	SWNENW	31	09S	12W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094454-00	IR	1.00 C	360.00	NWNWSE	25	09S	13W	BE&			PAINTER CREEK	BARRETT RANCH INC
S41A W094455-00	IR	1.65 C	594.00	NWNWNW	31	09S	12W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094456-00	IR	1.05 C	390.00	SWNESENE	36	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094457-00	IR	2.50 C	900.00	SWNENW	31	09S	12W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094458-00	ST	30.00 G	7.56	SESE	33	09S	13W	BE&			RAPE CREEK	BARRETT RANCH INC
S41A W094460-00	IR	2.25 C	810.00	SWSENE	36	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094461-00	IR	1.50 C	540.00	SESESW	25	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094462-00	IR	2.38 C	855.00	SWSENWSE	28	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094463-00	IR	2.13 C	765.00	NWNWSW	32	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094464-00	IR	.63 C	225.00	SENWSE	28	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094465-00	IR	2.00 C	1,460.00	NESESE	33	09S	13W	BE			RAPE CREEK	BARRETT RANCH INC
S41A W094466-00	IR	1.05 C	441.00	SESENE	36	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094467-00	IR	.45 C	189.00	NESENE	36	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094468-00	IR	2.05 C	861.00	SENENW	36	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094469-00	IR	1.00 C	360.00	NWNENE	36	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094470-00	IR	1.00 C	360.00	NWNWSW	32	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC
S41A W094471-00	IR	.88 C	315.00	NESESE	33	09S	13W	BE			RAPE CREEK	BARRETT RANCH INC
S41A W094472-00	IR	.50 C	180.00	SESWSW	34	09S	13W	BE			ALKALI CREEK	BARRETT RANCH INC
S41A W094473-00	IR	1.00 C	360.00	SESWSW	34	09S	13W	BE			ALKALI CREEK	BARRETT RANCH INC
S41A W094474-00	IR	1.25 C	450.00	SENWSE	25	09S	13W	BE			DUNLAP CREEK	BARRETT RANCH INC
S41A W094475-00	IR	4.93 C	1,773.00	NWNWSW	32	09S	13W	BE			HORSE PRAIRIE CREEK	BARRETT RANCH INC

NOTE: * - VERIFIED WATER RIGHT, G - GALLONS/MIN C - CUBIC FEET/SEC, X - UNNAMED TRIBUTARY TO SOURCE, & - ONLY FIRST POD LISTED

WATER RIGHT	USE	RATE	VOLUME	POINT OF DIVERSION QTR SCTN	SC	TWP	RGE	CN	UT	SOURCE NAME	OWNER NAME		
S41A W094714-00	IR	12.50 C	1,500.00			00	00	BE&		HANSEN CREEK	HANSEN LIVESTOCK CO		
S41A W095467-00	IR	2.80 C	1,354.75			00	00	BE		JUNCTION CREEK	SNOWLINE GRAZING ASSN		
S41A W095469-00	IR	3.63 C	1,753.96			00	00	BE		JUNCTION CREEK	SNOWLINE GRAZING ASSN		
S41A W095468-00	IR	1.63 C	786.26			00	00	BE		JUNCTION CREEK	SNOWLINE GRAZING ASSN		
S41A Z190491-00	FW	20.00 C	1,950.00			00	00	BE		NEPEE CREEK	USA (DEPT OF INTERIOR FISH & WI		
S41A W192479-00	DM	2.00 C	1.00	E2NWNW	21	01S	01E	BE	X	ANTELOPE CREEK	WALSH	LOIS	M
											WALSH	EUGENE	C
G41A E098788-00	DM	20.00 G	1.63	SESE	33	02S	15W	BE		WELL	TUCKER	LARRY	
											TUCKER	DOROTHY	J
G41A W027942-00	DM	5.00 G	2.00	NWNWNE	12	08N	08E	ME			BLUMER	RUTH	L
G41A C050115-00	ST	7.00 G	2.11	SESESW	32	08S	12W	BE		WELL	USA (DEPT OF INTERIOR BUREAU OF		
S41A W137151-00	ST		4.03	E2W2	36	08S	12W	BE	X	SHEEP CORRAL GULCH	MONTANA, STATE OF BOARD OF LAND		
G41A W053142-00	ST	4.49 G	1.88	SENWSW	16	08S	13W	BE		RESERVOIR SPRING	USA (DEPT OF AGRICULTURE FOREST		
S41A W053140-00	ST	4.49 G	1.92	NWSESE	17	08S	13W	BE		WATSON CREEK RESERVOIR	USA (DEPT OF AGRICULTURE FOREST		
G41A W053156-00	ST	4.49 G	1.88	SWNENE	20	08S	13W	BE		WATSON CREEK SPRING	USA (DEPT OF AGRICULTURE FOREST		
G41A C082946-00	ST	1.00 G	.14	SENWNE	20	08S	13W	BE		GROUNDWATER	USA (DEPT OF AGRICULTURE FOREST		
G41A W053141-00	ST	4.49 G	1.88	NWSENW	20	08S	13W	BE		BROWNS MEAD SPRING	USA (DEPT OF AGRICULTURE FOREST		
S41A W053150-00	ST	4.49 G	1.88	SESESE	20	08S	13W	BE		WATSON CREEK, SOUTH FORK	USA (DEPT OF AGRICULTURE FOREST		
S41A W137080-00	ST		3.63	W2	21	08S	13W	BE	X	SAGEBRUSH CREEK	MONTANA, STATE OF BOARD OF LAND		
S41A W137066-00	ST		6.45	S2	22	08S	13W	BE		WATSON CREEK	MONTANA, STATE OF BOARD OF LAND		
S41A W137065-00	ST		5.64	SWSW	23	08S	13W	BE		WATSON CREEK	MONTANA, STATE OF BOARD OF LAND		
S41A W049613-00	ST	5.00 C	2,250.00	E2SW	26	08S	13W	BE&		WATSON CREEK	BANNACK GRAZING ASSOC		
S41A W117656-00	IR	1.56 C	190.50	SENWNW	28	08S	13W	BE&		WATSON CREEK	WELLBORN	WILLIAM	R
											WELLBORN	HELEN	
S41A W049566-00	IR	.94 C	485.62	SENWNW	28	08S	13W	BE&		WATSON CREEK	ROBERTS	DICK	
											WELLBORN	JOSEPH	R
S41A W095554-00	IR	.31 C	180.62	SENWNW	28	08S	13W	BE&		WATSON CREEK	WELLBORN	WILLIAM	R
S41A W137079-00	ST		1.51	S2NW	28	08S	13W	BE	X	BADGER GULCH	MONTANA, STATE OF BOARD OF LAND		
G41A W095555-00	IR	.19 C	97.12	NWSWSE	28	08S	13W	BE		BLAIRFIELD SPRING	WELLBORN	WILLIAM	R
G41A W049565-00	IR	.56 C	291.37	S2SWSE	28	08S	13W	BE		BLAIRFIELD SPRINGS	ROBERTS	DICK	
											WELLBORN	JOSEPH	R
S41A W053154-00	ST	4.49 G	1.88	NENESW	29	08S	13W	BE		BROWN CREEK	USA (DEPT OF AGRICULTURE FOREST		
S41A W049564-00	IR	3.56 C	1,845.37	NWNESW	29	08S	13W	BE		BROWNS CANYON CREEK	ROBERTS	DICK	
											WELLBORN	JOSEPH	R
S41A W095553-00	IR	1.19 C	615.12	NWNESW	29	08S	13W	BE		BROWNS CANYON CREEK	WELLBORN	WILLIAM	R
S41A W117653-00	IR	2.50 C	305.00	NWNESW	29	08S	13W	BE&		BROWNS CANYON DITCH	WELLBORN	WILLIAM	R
											WELLBORN	HELEN	
S41A W111102-00	IR	7.50 C	1,365.00	NESESW	29	08S	13W	BE&		BROWNS CANYON CREEK	ROBERTS	DICK	
											WELLBORN	JOSEPH	R
											ROBERTS LIVESTOCK CO		
S41A W095356-00	IR	3.00 C	900.00	NESESW	29	08S	13W	BE		PAINTER CREEK, EAST FORK	SHAFFNER	DON	K

NOTE: * - VERIFIED WATER RIGHT, G - GALLONS/MIN C - CUBIC FEET/SEC, X - UNNAMED TRIBUTARY TO SOURCE, & - ONLY FIRST POD LISTED

WATER RIGHT		USE	RATE	VOLUME	POINT OF DIVERSION QTR	SCTN	SC	TWP	RGE	CN	UT	SOURCE NAME	OWNER NAME
G41A	C000076-00	DM	40.00 G		SESENE	4	13S	09W	BE			WELL (DEPTH - 65 FT)	MARTINELL, LEE CO
S41A	W000563-00	IR	1.88 C	513.10	NWSWSW	5	16S	11W	BE			COTTONWOOD CREEK	MONTGOMERY JOYCE I
													PYLE TRUST
S41A	W000564-00	IR	7.50 C	2,052.40	NENWNE	3	15S	11W	BE			COTTONWOOD CREEK	MTA INVESTMENT CO
G41A	C001250-00	DM	20.00 G		SESE	25	09S	14W	BE			WELL (DEPTH - 80 FT)	HIRSCHY, DICK CATTLE CO
G41A	C001657-00	ST	10.00 G		SWSE	7	12S	09W	BE			WELL (DEPTH - 36 FT)	BRIGGS RANCH INC
G41A	C002169-00	ST	8.00 G		SWSW	36	09S	11W	BE			WELL	MONTANA, STATE OF BOARD OF LAND
S41A	W002495-00	IR	2.00 C	840.00	NENESE	32	13S	06W	BE			WARM SPRINGS CREEK	PASSMORE, DORA ESTATE OF
S41A	W002496-00	IR	1.63 C	682.00	SESWSW	34	13S	06W	BE			TRAIL CREEK	RODY GUSTAV K
S41A	W002497-00	DM	.13 C	1.50	NENESE	32	13S	06W	BE			WARM SPRINGS CREEK	PASSMORE, DORA ESTATE OF
G41A	C003145-00	DM	20.00 G		NWSE	19	10S	10W	BE			WELL (DEPTH - 77 FT)	MONTANA, STATE OF DEPT OF FISH
G41A	W003170-00	IR	.10 C	150.00	SENESE	32	13S	06W	BE			LITTLE SWAMP SPRINGS	RODY GUSTAV K
S41A	W003171-00	IR	.38 C	150.00	SWSWSW	33	13S	06W	BE	X			RODY GUSTAV K
G41A	C003425-00	ST	3.00 G		NWNE	18	10S	12W	BE			WELL	WELLBORN WILLIAM R
S41A	W004553-00	IR	3.00 C	780.00	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
S41A	W004554-00	IR	2.65 C	265.00	SESWSE	32	08S	13W	BE&			BROWN'S CANYON CREEK	KWD ASSOCIATES L C
S41A	W004555-00	IR	4.75 C	1,235.00	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
G41A	W004556-00	IR	1.00 C	240.00	SENESW	9	09S	13W	BE&			THREE SPRINGS	KWD ASSOCIATES L C
S41A	W004557-00	IR	1.00 C	240.00	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
S41A	W004558-00	IR	1.00 C	240.00	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
S41A	W004559-00	IR	2.50 C	600.00	SESWSE	32	08S	13W	BE&			BROWN'S CANYON CREEK	KWD ASSOCIATES L C
S41A	W004560-00	IR	4.00 C	960.00	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
S41A	W004561-00	IR	.90 C	216.00	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
S41A	W004562-00	IR	3.08 C	799.50	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
S41A	W004563-00	IR	.50 C	120.00	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
S41A	W004564-00	IR	2.50 C	600.00	NENENE	9	09S	13W	BE&			WATSON CREEK	KWD ASSOCIATES L C
S41A	W004565-00	IR	.50 C	120.00	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
S41A	W004566-00	IR	1.00 C	260.00	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
S41A	W004567-00	IR	10.00 C	2,600.00	NWNENE	6	09S	13W	BE&			PAINTER CREEK	KWD ASSOCIATES L C
G41A	C004957-00	ST	10.00 G		NWNW	18	13S	01E	BE			WELL	MOORSE CREEK GRAZING ASSN
S41A	W005000-00	IR	3.50 C	1,050.00	NWNESW	21	14S	07W	BE			JUNCTION CREEK	HIGH MOUNTAIN RANCHES INC
G41A	C005454-00	DM	20.00 G		NW	34	09S	12W	BE			WELL (DEPTH - 68 FT)	CHRISTENSEN JAY D
G41A	C006494-00	ST	20.00 G		SESW	3	14S	01E	BE			WELL	MONTANA, STATE OF BOARD OF LAND
G41A	W006740-00	IR	1.25 C	420.00	NENW	13	10S	13W	BE			CHERYL'S SPRING	HREN RANCHES INC
S41A	W007595-00	MN	50.00 G	1.00	SENWNE	28	10S	15W	BE			FRYING PAN CREEK, SOUTH	TENNECO OIL CO
S41A	W007596-00	MN	50.00 G	1.00	SENESE	20	10S	15W	BE			FRYING PAN CREEK, NORTH	TENNECO OIL CO
G41A	C008712-00	DM	10.00 G		S2	29	10S	10W	BE			WELL (DEPTH - 85 FT)	CAMPBELL ROLLAND
													CAMPBELL S
													CAMPBELL CAROL S
G41A	C008912-00	ST	15.00 G		SWNESW	22	14S	03W	BE			WELL (DEPTH - 148 FT)	UK HOLDINGS LTD
G41A	W009370-00	DM	10.00 G	16.10	NENWNE	15	14S	10W	BE			WELL	THOMPSON, JOHN B MEDICAL CORP P
S41A	W009371-00	IR	4.17 C	1,131.91	NENENE	9	16S	11W	BE			BEAR CREEK	MTA INVESTMENT CO
S41A	W009372-00	IR	4.17 C	1,131.92	NENENE	9	16S	11W	BE			BEAR CREEK	MTA INVESTMENT CO
S41A	W009373-00	IR	.75 C	214.16	SWNWSW	31	13S	10W	BE			CABIN CREEK	HIGH MOUNTAIN RANCHES INC
G41A	W009374-00	IR	2.00 C	670.25	NESWNE	15	14S	10W	BE			JOHNSON SPRING	THOMPSON, JOHN B MEDICAL CORP P
S41A	W009375-00	IR	3.13 C	855.17	SENWNE	15	14S	11W	BE			BIG SHEEP CREEK	THOMPSON, JOHN B MEDICAL CORP P
S41A	W009378-00	IR	7.50 C	3,150.00	NWNESW	35	13S	09W	BE			LITTLE SHEEP CREEK	KEPPNER DONNA KAY
													KEPPNER LEO
S41A	W009379-00	IR	2.00 C	1,250.00	SWSWNW	36	13S	09W	BE			RED ROCK RIVER	KEPPNER DONNA KAY
													KEPPNER LEO
S41A	W009380-00	IR	3.00 C	1,260.00	SWSWNW	36	13S	09W	BE			RED ROCK RIVER	KEPPNER DONNA KAY

DEPARTMENT OF NATURAL RESOURCES & CONSERVATION
WATER RIGHTS BUREAU

Purpose Codes

AS - Agricultural spraying
CM - Commercial
DM - Domestic
DW - Dewatering
EC - Erosion control
ED - Exploratory drilling
FC - Flood control
FD - Flood detention
FF - Flow-through fish pond, nonconsumptive
*FL - Flood irrigation
FP - Fire protection
FR - Fish raceways
FS - Fish pond
FW - Fish and wildlife
GE - Geothermal
GH - Geothermal, heating
GP - Geothermal, power generation
IN - Industrial
*IR - Irrigation
IS - Institutional
LG - Lawn and garden
MC - Municipal
MD - Multiple domestic
MN - Mining
*NF - New flood irrigation
*NI - New irrigation
*NS - New sprinkler irrigation
NV - Navigation
OF - Oil well flooding
OT - Observation and testing of groundwater aquifer
PA - Pollution abatement
PG - Power generation
PN - Power generation, nonconsumptive
RC - Recreation
SC - Sediment control
*SF - Supplemental flood irrigation
*SI - Supplemental irrigation
*SP - Sprinkler irrigation
*SS - Supplemental sprinkler irrigation
ST - Stock
WF - Waterfowl
WI - Wildlife

*irrigation codes

Form No 78 1 N2800

416

STATEMENT OF CLAIM FOR EXISTING WATER RIGHTS

IRRIGATION

For the Water Courts of the State of Montana

015779

RECEIVED
MAY 13 1981
MONTANA DNRC
BOZEMAN FIELD OFFICE

HA-U
10-038-01-03
#40

1 Owner of Water Right _____ / _____ / _____
Last First Middle Initial

Co Owner or Other Interest Owner _____ / _____ / _____
Last First Middle Initial

Address _____

City Cardwell State Montana Zip Code 59721

Home Phone No 287-3695 Business Phone No 287-3695

(2) Person completing form SAME AS ABOVE _____ / _____ / _____
Last First Middle Initial

Address _____

City _____ State _____ Zip Code _____

Home Phone No _____ Business Phone No _____

3 Name of ditch, creek or river Black Ditch

(3) Use: ☒ Irrigation

(4) Method of Irrigation Use: E ☒ Sprinkler [ ] Furrow ☒ Flood

5 Source of Water: (Check Only One)

☒ Spring Name Brooks Spring

[ ] Well Name _____

[ ] Stream Name _____ Tributary of South Boulder River

[ ] Lake Name _____ Stream _____
Tributary of _____

[ ] Reservoir Name _____ Stream _____
Tributary of _____

6 Point of Diversion County Madison

NE ¼ NE ¼ SW ¼, Section 35, T 1 ☒S, R 3 ☒E

Lot _____ Block _____, Subdivision _____

7 Means of Diversion:

[ ] Pump Capacity _____ gpm

☒ Headgate and ditch or pipe

[ ] Flood and dike

8 Means of Conveyance

☒ Ditch

[ ] Pipeline

[ ] Other Explain _____

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JEFFERSON RIVER BASIN
BASIN 41G
ABSTRACT OF WATER RIGHT

07/24/

WATER_RIGHT_NUMBER_41G--W-015779-00

OWNERS:

PRIORITY_DATE: AUG 9, 1920 9:30 AM

FLOW_RATE: 0.25 CFS

VOLUME:

THE TOTAL VOLUME OF THIS RIGHT SHALL NOT EXCEED THE AMOUNT HISTORICALLY USED FOR A BENEFICIAL PURPOSE.

SOURCE: SPRING, TRIBUTARY OF SOUTH BOULDER RIVER

ALSO KNOWN AS BROOKS SPRING

MAXIMUM_ACRES: 140.00

PURPOSE_USE(S): IRRIGATION

PERIOD_OF_USE: JUNE 1 TO SEPT 4

POINTS_OF_DIVERSION_AND_OTHER_DIVERSION:

	LOT	BLK	QTR	SEC	SEC	TWP	RGE	COUNTY
			NENESW	35	01N	03W	MADISON	HEADGATE

PLACE_OF_USE_FOR_IRRIGATION

	ACRES	LOT	BLK	QTR	SEC	SEC	TWP	RGE	COUNTY
001	3.00			SESWSE	26	01N	03W		MADISON
002	35.00			NWNW	23	01N	03W		MADISON
003	25.00			SWNW	23	01N	03W		MADISON
004	30.00			NWSW	23	01N	03W		MADISON
005	40.00			W2SE	14	01N	03W		MADISON
006	7.00			E2E2NE	22	01N	03W		MADISON
TOTAL	140.00								

REMARKS: THE WATER RIGHTS FOLLOWING THIS STATEMENT ARE SUPPLEMENTAL, WHICH MEANS THE RIGHTS HAVE OVERLAPPING PLACES OF USE. THE RIGHTS CAN BE COMBINED TO IRRIGATE ONLY OVERLAPPING PARCELS OF THE CLAIMANTS' TOTAL 140.00 ACRES. EACH RIGHT IS LIMITED TO THE FLOW RATE AND PLACE OF USE OF THAT INDIVIDUAL RIGHT. THE SUM TOTAL VOLUME OF THESE WATER RIGHTS SHALL NOT EXCEED THE AMOUNT HISTORICALLY USED FOR A BENEFICIAL PURPOSE.
W015779-00, W018678-00, W018679-00, W018680-00, W018681-00, W018682-00, W018683-00

A FULL UNDERSTANDING OF YOUR WATER RIGHT CAN BE OBTAINED ONLY BY COMPARING YOUR PRIORITY DATE WITH THE PRIORITY DATES OF OTHER WATER RIGHTS IN THE BASIN THAT MAY AFFECT THE USE OF YOUR RIGHT. ALSO, YOUR WATER RIGHT MAY BE SUBJECT TO WATER RIGHTS IN ADJOINING BASINS OR SUB-BASINS AS WELL AS BEING SUBJECT TO OTHER WATER RIGHTS ON YOUR SOURCE OF SUPPLY. FINALLY, YOUR WATER RIGHT MAY BE SUBJECT TO INDIAN AND FEDERAL WATER RIGHTS.

SEE GENERAL FINDINGS OF FACT AND CONCLUSIONS OF LAW FOR FURTHER DEFINITION OF THIS RIGHT.

LAND SURVEYS AND DESCRIPTIONS

LAND SURVEYS AND DESCRIPTION

The precise statement of where a parcel of real estate is located is called the *"legal description."* Whenever real estate is conveyed from one owner to another, it is necessary to know and state the location of the boundaries. The same process can be followed in describing the location of an irrigated field in the water adjudication process.

Rectangular System of Public Land Survey

The system provides for the subdivision of public lands into a rectangular pattern of townships, sections, and quarter-sections. The system was authorized by the Continental Congress in 1785 so that vast regions of the country could be easily surveyed and much of the land transferred into private ownership. The simplicity of the rectangular system makes it ideal for describing larger tracts of agricultural land. Some smaller tracts require that other methods be used.

Montana Surveys

Montana lands are referenced to an initial point located near Willow Creek. A north-south line called the *"principal meridian"* and east-west line called a *"base line"* are extended through the initial point. *"Standard parallels"* of latitude are located at 24-mile intervals north and south from the base line. Likewise, *"guide meridians"* are located every 24 miles east and west of the principal meridian. Because guide meridians are true north lines, they converge toward the north pole. Hence, the north boundary of 24-mile blocks will be less than 24 miles. See Figure 1.

The 24-mile blocks are further subdivided into townships by *"range lines"* running north and south and *"township lines"* running east and west at 6-mile intervals. The townships are nearly rectangular, but, due to polar

convergence, the north side is also short. Townships are designated by numbers corresponding to the number of 6-mile blocks (both north or south, and east or west) that the township in question lies from the initial point. In Figure 1, T3N, R6W refers to the township in the third row north of the base line and in the sixth column west of the principal meridian.

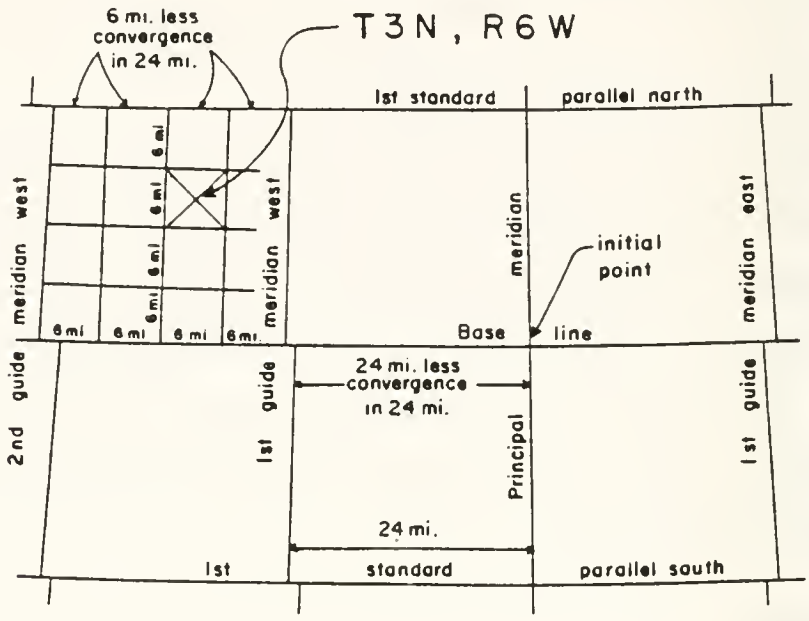


Figure 1. Land division under the rectangular system of public survey.

Sections

Townships are further subdivided into sections as is shown in Figure 2. The subdivision is started in the northeast corner of the township and proceeds west and south through the township. Most of the sections will be 1 mile square and contain 640 acres. All survey errors are placed in the last half mile on the north and west of the township. In addition, the westerly column of sections will be less than 1 mile on a side due to convergence. Section numbering is indicated in Figure 2. Each standard section can be further subdivided into smaller tracts as shown in Figure 3.

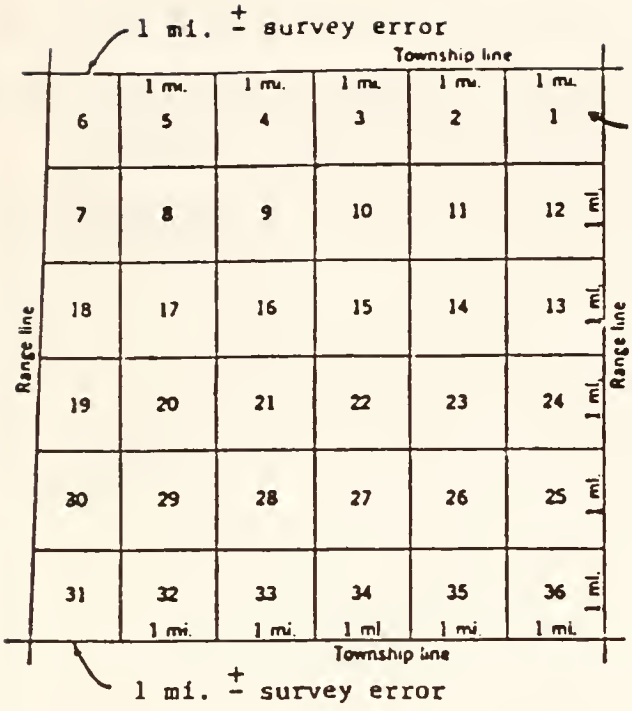


Figure 2. Subdivision of township into sections.

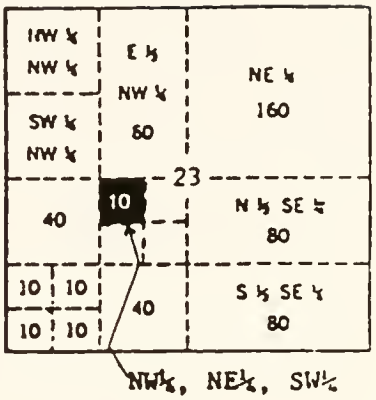


Figure 3. Subdivision of section number 23.

Lots

In sections that are not standard in size (that is, 640 acres), all regular 40-acre tracts are first identified, and then the remaining portions are broken into lots normally having between 10 and 50 acres. Surveys cannot be made with complete accuracy, and surveys of large, scattered tracts were sometimes made from starting points that did not coincide with a standard parallel or guide meridian. Thus, where surveys joined, some sections were not full size, and some lands were "leftovers." Also, all sections on the west boundary of a township were not full size due to meridian convergence. Natural boundaries such as large lakes or rivers and reservation boundaries can keep sections from being full size. The last half mile distance on the north and west of the township was used to absorb survey errors or discrepancies, with these portions of sections given lot numbers. Lots can thus occur in the North Half of Sections 1-6 due to survey errors, leftover

land, or boundary interference; in the West Half of Sections 6, 7, 18, 19, 30, and 31 due to error, leftovers, convergence, or boundary interference;, and in any of the remaining sections due to boundary interference. The actual dimensions of any lot were recorded with the filed map. Lot numbers can also be used when land is subdivided.

Legal Description

The legal description of a parcel of land under the rectangular system always begins with the smallest unit. Assume that Section 23 as shown in Figure 3 is located 8 townships south and 12 townships east of the Montana Principal Meridian. The small, cross-hatched 10-acre parcel would be described as follows:

> "The NW1/4, NE1/4, SW1/4, Section 23, T8S, R12E, Montana Principal Meridian, and contains 10 acres, more or less."

The legal description of a parcel given a lot number might be, for example, Lot 4, Section 6, T12N, R2E, Montana Principal Meridian.

Metes and Bounds

This method identifies a tract of land by giving the direction and length of its sides. The point of beginning must be fixed by stating its direction and distance from a section or quarter-section corner. An example of a metes and bounds description such as found on the deed of a real property follows:

> "Beginning at a concrete monument located 1253.3 feet south and 49.6 feet west from the NE corner, Section 10, T8S, R12E, Montana Principal Meridian, at the center lines of Washington and Garfield Roads in the City of Woodland, County of Lewis and Clark, State of Montana, thence
>
> North 81°44' west along the southerly line of Elm Street for a distance of 939.0 feet to an iron pin on the easterly line of Tracy Road;
>
> South 10°04' west along the easterly line of said Road for a distance of 833.7 feet to an iron pin;
>
> South 63°18' east along the northerly iron fence for a

distance of 182.7 feet to a cross cut on a stone;

South 77°42' east continuing along said iron fence for a distance of 310.9 feet to an iron post;

North 67°47' east continuing along said iron fence for a distance of 638.2 feet to a spike in the southwest corner of a 15-inch fir tree;

North 1°40' east along a woven wire fence and the property now, or formerly, belonging to John Jones for a distance of 593.1 feet to the point of beginning;

All bearings being referred to the true meridian; the tract containing 18.59 acres, more or less; and being shown on the plat drawn by John Doe, Registered Land Surveyor, dated . . ., which is attached hereto and made a part thereof."

A SECTION OF LAND—640 ACRES

80 Chains—320 Rods—5,280 Feet

40 CHAINS

7.92 inches are 1 link
25 links are 1 rod
4 rods or 100 links are 1 chain.
A rod is 16 1/2 feet.
A pole is 16 1/2 feet.
A chain is 66 feet or four rods.
A mile is 320 rods, 80 chains, or 5,280 feet.
An acre contains 43,560 square feet (4,840 sq. yds.)
An acre contains 160 square rods.
An acre is 208.7 (plus) feet square.
An acre is 8 rods wide by 20 rods long, or any two numbers (of rods) whose product is 160
Square feet x .000023= acres.
Square chains x 0.10= acres.
40 chains equals 160 rods or 2,640 feet.

(160 ACRES)

20 CHAINS

(80 ACRES)

80 Rods or 1,320 Feet

10 CHAINS

(20 ACRES)

40 Rods or 660 Ft.

5 Chains 5 Acres 20 Rods or 330 Ft.

5 Chains 5 Acres 20 Rods or 330 Ft.

(10 ACRES) 40 Rods or 660 Ft.

(40 ACRES)

80 Rods—20 Chains or 1,320 Feet

36	31	32	33 T. 36 N.	34	35	36	31
1	6	5	4 T. 35 N.	3	2	1	6
12	7	8	9	10	11	12	7
13	18	17	16	15	14	13	18
24	19	20	21	22	23	24	19
25	30	29	28	27	26	25	30
36	31	32	33 T. 35 N.	34	35	36	31
1	6	5	4 T. 34 N.	3	2	1	6

R. 22 E. R. 23 E. R. 23 E. R. 24 E.

NW NW (Lot 4) 40 Acres	NE NW (Lot 3) 40 Acres	NW NE (Lot 2) 40 Acres	NE NE (Lot 1) 40 Acres
SW NW (Lot 5) 40 Acres	SE NW 40 Acres	SW NE 40 Acres	SE NE 40 Acres
NW SW (Lot 6) 40 Acres	NE SW 40 Acres	NW SE 40 Acres	NE SE 40 Acres
SW SW (Lot 7) 40 Acres	SE SW 40 Acres	SW SE 40 Acres	SE SE 40 Acres

NW — NE — SW — SE — SEC. 6

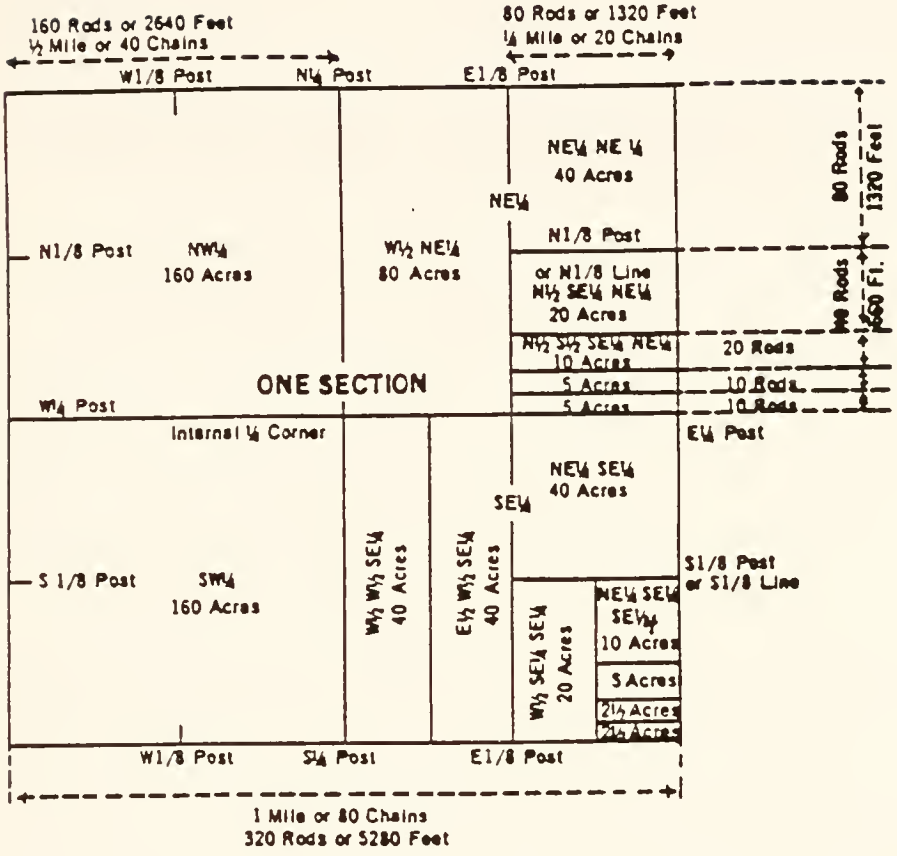
Sectional Map of Township with Adjoining Sections

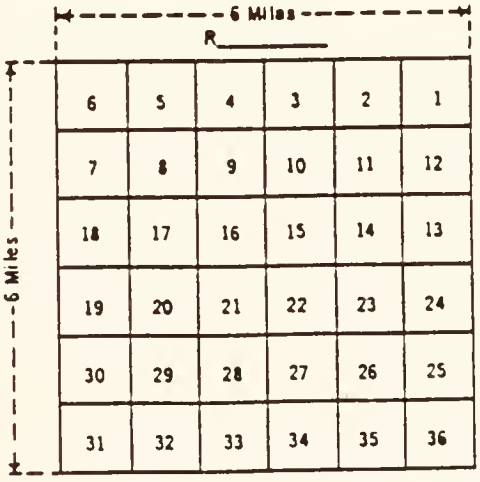
Subdivisions of a Section

SW 1/4 SE 1/4 SE 1/4

NW 1/4 SE 1/4 SE 1/4 SE 1/4

Standard lots are usually in the north and west sections of a township, and the acreage may be more or less than 40


160 Rods or 2640 Feet
½ Mile or 40 Chains
80 Rods or 1320 Feet
¼ Mile or 20 Chains
W1/8 Post
N¼ Post
E1/8 Post
NE¼ NE ¼
40 Acres
NE¼
N1/8 Post
N1/8 Post
NW¼
160 Acres
W½ NE¼
80 Acres
or N1/8 Line
N½ SE¼ NE¼
20 Acres
80 Rods
1320 Feet
N½ S½ SE¼ NE¼
10 Acres
20 Rods
ONE SECTION
5 Acres
10 Rods
W¼ Post
5 Acres
10 Rods
Internal ¼ Corner
E¼ Post
NE¼ SE¼
40 Acres
SE¼
S1/8 Post
or S1/8 Line
S 1/8 Post
SW¼
160 Acres
W½ W½ SE¼
40 Acres
E½ W½ SE¼
40 Acres
W½ SE¼ SE¼
20 Acres
NE¼ SE¼ SE¼
10 Acres
5 Acres
2½ Acres
2½ Acres
W1/8 Post
S¼ Post
E1/8 Post
1 Mile or 80 Chains
320 Rods or 5280 Feet


6 Miles
R
6 Miles
6 5 4 3 2 1
7 8 9 10 11 12
18 17 16 15 14 13
19 20 21 22 23 24
30 29 28 27 26 25
31 32 33 34 35 36

WATER MEASUREMENT

WATER MEASUREMENT

The information contained in this section has been assembled from a variety of sources. Personnel at the DNRC Water Resources Regional Offices can provide assistance in using this information and making accurate water measurements. Other information on water measurement exists, and this collection of materials serves only to provide a sample of various methods of water measurement and measuring devices.

MINER'S INCH WATER MEASUREMENT

The miner's inch is defined as the quantity of water that will flow through an opening 1-inch square in a vertical wall under a given pressure head. Pressure heads ranging from 4 to 7 inches were used by the miners and settlers.

Each of the western states defines the miner's inch in terms of 1 cfs.

One miner's inch is designated as 1.50 cfs in southern California, Idaho, Kansas, New Mexico, North Dakota, South Dakota, and Nebraska.

In Arizona, northern California, Montana, Nevada, and Oregon, 1 miner's inch is equal to 1/40 cfs.

In Colorado, 38.4 miner's inches is considered equal to 1 cfs.

WATER CONVERSION TABLE

One miner's inch equals	11.22	gallons per minute
or	.025	cubic foot per second
One cubic foot per second equals	7.48	gallons per second
or	448.8	gallons per minute
or	1.	acre-inch per hour
or	1.98	acre-feet per day
or	724.	acre-feet per year
or	646,315.	gallons per day
or	40.	miner's inches in Montana
One acre-foot equals	325,851.	gallons
or	43,560.	cubic feet, or one foot of water on one acre
or	12.	acre-inches
(NOTE: One acre-inch per day requires 18.7 gpm continuous flow)		
One gallon equals	8.34	pounds
or	231.	cubic inches
or	.134	cubic foot
One gallon per minute equals	1,440.	gallons per day (24 hrs.)
or	.002	cubic foot per second
100 gallons per minute equals	.442	acre-foot per day
1,000,000 gallons per day equals	1.55	cubic feet per second
or	694.	gallons per minute
or	3.07	acre-feet per day
or	1,121.	acre-feet per year
1 foot head equals	.433	pounds per square inch pressure
1 pound per square inch equals	2.31	feet head of water pressure

QUICK CONVERSIONS

mi	x	11.22	=	gpm	cfs	x	40.	=	mi
mi	÷	40.	=	cfs	cfs	x	448.8	=	gpm
mi	x	.0495	=	acre ft/d	cfs	x	1.98	=	acre ft/d
gpm	÷	11.22	=	mi	acre ft/d	÷	1.98	=	cfs
gpm	÷	448.8	=	cfs	acre ft/d	x	226.29	=	gpm
gpm	÷	226.29	=	acre ft/d	acre ft/d	÷	.0495	=	mi

acre ft/d = acre-feet per day
cfs = cubic feet per second
gpm = gallons per minute
mi = miner's inch

Water Measurement

MT 9125 (AG)

The Float-area Method

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

What is the float-area method?

In the float-area method of water measurement, the cross sectional area of the channel is measured and a float such as a stick is timed as the water carries it down a measured distance. Combining these measurements and multiplying by an appropriate coefficient gives the flow rate.

Advantages/disadvantages

The float-area method of water measurement gives only an approximate measure of the flow rate. Accuracy within about 10 percent, more or less, is possible. The method is much better than a guess and is useful where a more elaborate installation is not warranted or would be impossible to install, and where high accuracy is not required. If the measurements are made and recorded carefully, they may be accepted by a court.

The accuracy of the method is limited by many factors including difficulty in determining the exact cross sectional area, using stream segments greater than about 10 feet in width on wide streams, changes in stream depth along the channel reach, cross currents, wind forces, and errors in measuring time and distance. There also is a lack of precision in the coefficients (see Table 1.)

Water measurement

Find a straight section of channel about 20 to 100 feet long where the width and depth are fairly uniform, as illustrated in Figure 1. Measure and stake the exact distance between two points. Determine the dimensions of the channel at these points. The dimensions of these upstream and downstream cross sections will be averaged and used in final calculations. If the channel is very uniform it is only necessary to determine the area of one cross section at the center of the reach.

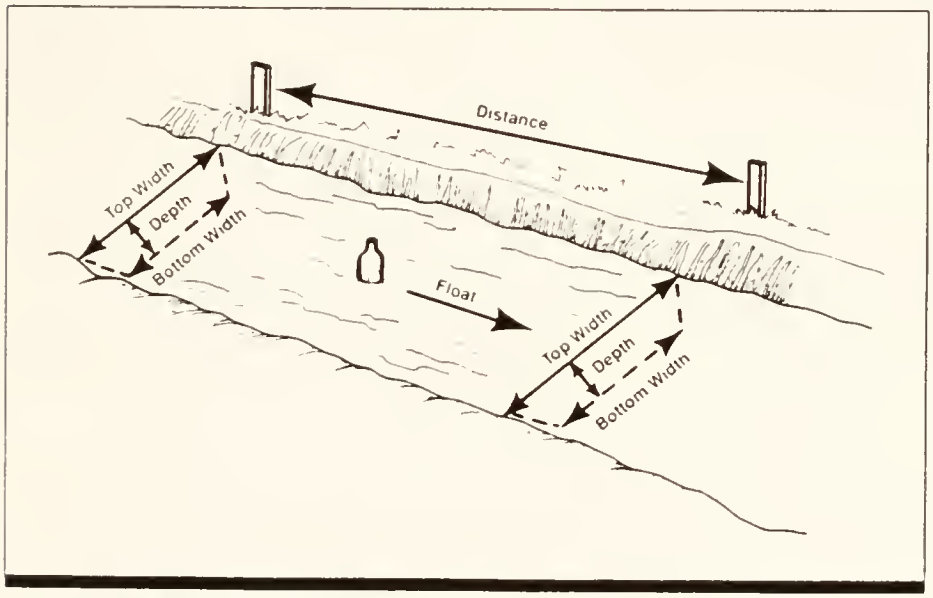


Figure 1. Using the float-area method to measure flow rate

MONTANA STATE UNIVERSITY
1893-CENTENNIAL-1993
Extension Service

Funded by the Ag Energy Conservation Program, Montana Department of Natural Resources and Conservation. Sponsored by Gallatin County Conservation District.

The programs of the Montana State University Extension Service are available to all people regardless of race, creed, color, sex, handicap or national origin. Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Andrea Pagenkopf, Acting Vice President for Extension and Acting Director of Montana State University Extension Service, Bozeman, Montana 59717.

A-3

Water Should Be Measured Because . . .

Water measurement is the foundation of water management and economical crop production. Measuring and applying the proper amount of water saves you money and protects water resources by decreasing soil erosion, fertilizer leaching, and waste water problems.

Montana law requires measuring devices on all streams for which water commissioners have been appointed. A commissioner cannot deliver water unless measuring devices are in place. Eventually all Montana waters will be decreed. You can protect your water right by accurately measuring and recording flow rates and times of use.

Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

The top width of the channel can be measured by stretching a tape across the stream. Most stream cross sections are roughly trapezoidal in shape, and the bottom corners of the cross sections can be found by probing with a rod or board. When the bottom corners are delineated, the bottom width can be measured and the water depth can be measured at the corners. Some judgement is necessary. For a stream wider than about 10 feet, the depth is also measured at intermediate points. A rope with markers at reasonable intervals (about 10 feet) stretched across the channel and tied in place can be used to delineate the segments. On wide and deep channels you may need boots, waders, or even a boat.

The distance between the upstream and downstream cross sections and the time for the float to travel between them are used to determine the velocity of the water. Place a small float in the channel and measure the time it takes to move through the stretch selected. When there is more than one segment, as on wide streams, make this velocity determination in the center of each segment. The float should be released far enough upstream from the first section so that it is up to speed as it floats through. It is good practice to repeat the entire process in a second nearby stretch of channel.

The float should be something that is partially submerged such as a water-logged piece of wood or a bottle partly filled with water. A leaf or chip is too light and tends to be blown about and restrained by the surface tension of the water.

Because of the drag exerted on the water by the sides and bottom of the channel, the average water velocity is less than the velocity of the float. For this reason the measured float velocity should be multiplied by the appropriate coefficient shown in Table 1. The corrected velocity should then be multiplied by the cross-sectional area of the corresponding stream segment to obtain the flow rate.

The following example illustrates this water measurement method.

A float takes 22 seconds to travel 50 feet. The channel depth in the upstream section is 1.7 feet and in the downstream section it is 1.5 feet, giving an average channel depth of 1.6 feet. For a depth of 1.6 feet, from Table 1, the coefficient is .67. The top widths at the upstream and downstream sections are 3.0 and 3.4 feet giving an average top width of 3.2 feet. The bottom width at the upstream and downstream sections is 1.2 and 1.6 feet giving an average bottom width of 1.4 feet. The flow rate can be calculated by following these steps.

1. Find the cross-sectional area by adding the average top width to the average bottom width, dividing by 2, and multiplying by the average channel depth.

Cross-sectional area = (3.2 + 1.4)/2 x 1.6

= 3.7 square feet

2. Determine the float velocity by dividing the distance between cross sections by the time it takes the float to go from the upper to the lower cross section.

Float velocity = 50 feet/22 seconds

= 2.3 feet per second (fps)

Table 1. Coefficients for Converting Float Velocity to Water Velocity

Average Depth (in feet)	Coefficient
1	.66
2	.68
3	.70
4	.72
5	.74
6	.76
9	.77
12	.78
15	.79
20 and above	.80

3. Adjust the float velocity by multiplying it by the coefficient for the appropriate depth given in Table 1.

Average water velocity = 2.3 fps x .67 = 1.5 fps

4. Find the flow rate by multiplying the cross-sectional area (from Step 1) by the average water velocity (from Step 3).

Flow rate = 3.7 square feet x 1.5 fps

= 5.6 cubic feet per second (cfs)

For larger streams this procedure would be followed for each stream segment measured. The depth would be measured at the upper and lower ends of each segment, then averaged. The total flow rate would then be the sum of the flow rate in each segment. Calculations are simple, but should be carefully checked to avoid mistakes.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second x hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute x hours}}{450 \text{ x area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches x hours}}{40 \text{ x area irrigated in acres}}$$

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft^3), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

File under: Water Measurement
A-3 (Devices and Methods)
Issued January 1992 1642000192 MS

Water Measurement

MT 9124 (AG)

The Container Method

• Gerald L. Westesen, Professor of Civil and Agricultural Engineering, Agricultural Experiment Station

What is the container method?

The container method of water measurement involves using a watch and a container of known volume such as a one- or five-gallon bucket to determine water flow rates. Flow rates from sprinklers, gated pipe and siphons can be readily determined. For this method a stopwatch is useful but a watch measuring seconds is adequate.

Advantages

- The container method is quick, expedient and requires a minimal amount of equipment.
- Accuracy can be very good, within about five percent more or less, if care is taken and a large enough container is used so that the time interval is reasonable.
- If records are kept of the time and place of the measurement, the records would be acceptable in court.

Disadvantages

- The measurement is good for only a particular time and may have to be repeated under different conditions for the reading to be representative.
- Measurement from siphons or gated pipe may be difficult because the flow emerges from the pipe so close to the ground.

Sprinklers

Measurement of the flow from a sprinkler is easier if the impact arms of the two adjacent sprinklers are held back with small pieces of wire or trash. Then you will not be sprinkled as the adjacent sprinklers rotate. Slip a short length of garden hose over the end of the sprinkler, direct the flow into the container, and measure the time for the container to fill. The method is illustrated in Figure 1.

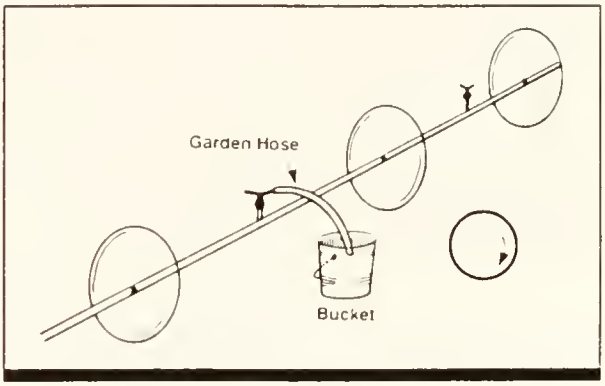


Figure 1. Measuring the discharge from a sprinkler using the container method

Water Should Be Measured Because . . .

Water measurement is the foundation of water management and economical crop production. Measuring and applying the proper amount of water saves you money and protects water resources by decreasing soil erosion, fertilizer leaching, and waste water problems.

Montana law requires measuring devices on all streams for which water commissioners have been appointed. A commissioner cannot deliver water unless measuring devices are in place. Eventually all Montana waters will be decreed. You can protect your water right by accurately measuring and recording flow rates and times of use.

Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

MONTANA STATE UNIVERSITY
Extension Service

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A-2

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft^3), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

By checking several sprinklers along a line, computing an average, and multiplying by the total number of sprinklers, the total flow from a sprinkler line can be calculated. Doing this measurement also presents an opportunity to check sprinkler nozzles for wear and uniformity. The method works for wheel and hand lines where the sprinkler type and discharge are uniform. It does not work with center pivots as the sprinklers have different flow rates, are usually too high to reach, and the "end gun" flow is usually too high to measure with a container.

Siphons and gated pipe

With water flowing from siphons or gated pipe, it may be necessary to dig a hole to set the bucket in before making the measurement. Several streams should be checked and an average calculated. For measurement, select representative gated pipe or siphons that are operating under uniform pressure.

Calculations

For example, if a five-gallon bucket is filled in 45 seconds, the calculations would be:

45 seconds = 45/60 = .75 minute

Flow rate = 5 gallons /.75 minute = 6.67 gallons per minute (gpm)

This technique can provide valuable information for the producer. For example, if there were 33 sprinklers per line and assuming all sprinklers were uniform, the total flow rate would be 6.67 gpm x 33 or 220 gpm. If the line irrigated a 44-acre field in 11 days or 11 x 24 (or 264) hours the average depth of water applied in inches would be:

$$\frac{\text{flow in gallons per minute x hours}}{\text{450 x area irrigated in acres}}$$

$$\frac{\text{220 gpm x 264 hours}}{\text{450 x 44 acres}} = 2.9 \text{ inches}$$

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second x hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute x hours}}{\text{450 x area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches x hours}}{\text{40 x area irrigated in acres}}$$

File under: Water Measurement
A-2 (Devices and Methods)
Issued November 1991 13520001191MS

Water Measurement

MT 9134 (AG)

FEB 12 1998

The Trajectory Method

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

What is the trajectory method?

The trajectory method is used to determine the discharge from a full, level pipe discharging into the air, as illustrated in Figure 1. This method is often used to measure the flow rate from a pump discharging into a ditch or pond. The flow rate depends on the inside diameter (I.D.) of the pipe and the water velocity. The water will shoot out further when the velocity is higher. Accuracy within about 10 percent, more or less, is possible.

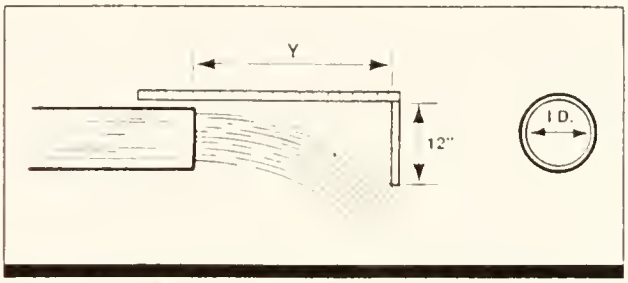

Figure 1. The trajectory method of measuring pipe discharge

Advantages

- The trajectory method is a quick, expedient, and reasonably accurate measurement method.
- The equipment needed is inexpensive and readily available.
- The measurements and the technique required are not complicated and the degree of accuracy is much better than a guess.
- If care is taken and the measurements made are recorded, they may be accepted by a court.

Disadvantages

- The method works only with pipes flowing full, and the discharge pipe must be level.
- The measurement is not nearly as precise as that from a meter and should be considered only a good estimate.

Water measurement

The flow rate is determined by measuring the inside diameter of the pipe and the distance, "Y," from the end of the pipe that it takes for the jet of water to drop a distance,

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A-12

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft³), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

facilitated by attaching a 12-inch leg at a right angle to an ordinary yardstick, as shown in Figure 1, or by using a carpenter's square. Discharges for various values of "Y" and various pipe diameters are shown in Figure 2. The flow rate is determined by entering the graph at the measured "Y" value, moving horizontally to the line of the proper pipe size, and then moving down to read the flow rate in gallons per minute (gpm). For example, with a "Y" value of 14 inches and a pipe with a 6-inch inside diameter, the flow rate is 420 gpm.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second} \times \text{hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute} \times \text{hours}}{450 \times \text{area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches} \times \text{hours}}{40 \times \text{area irrigated in acres}}$$

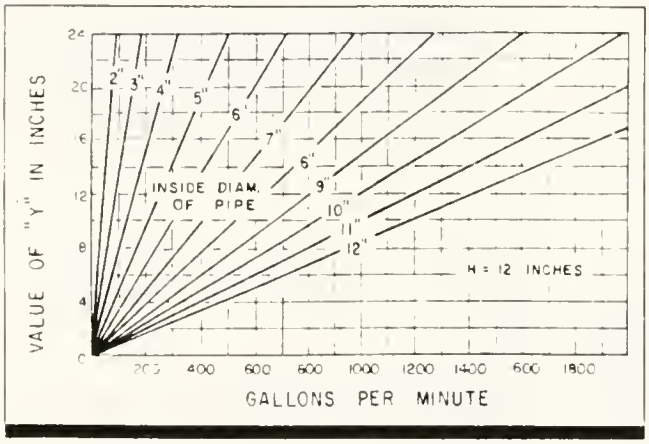

Figure 2. Discharge vs. "Y" for pipes with inside diameter of 2 inches to 12 inches

File under: Water Measurement
A-12 (Devices and Methods)
Issued January 1992 1662000192 MS

Water Measurement

MT 9133 (AG)

Siphons

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

Siphons as measuring devices

Siphons are commonly used in irrigation to convey water over a ditchbank. The same siphons can also be used to estimate the water flow rate when other, more common, measurement methods are not in place. The flow rate per siphon can be determined easily since the flow rate is a function of the siphon size and the head under which it is operating. By multiplying the number of siphons by the flow rate per siphon, the total flow rate at the field can be determined. Accuracy within about 10 percent, more or less, is possible.

Advantages

• Siphons are often already in place in a ditch for normal irrigation purposes.

• The cost of a measuring device is eliminated as virtually any irrigator already owns the carpenter's level and tape needed to make the measurements.

• Although the measurement is not as precise as those made with more sophisticated devices, it is much better than a guess and is quick and expedient. If care is taken, the measurement records may be accepted by a court.

Disadvantages

• The measurement taken is at the field. Any ditch loss between the point of diversion and the place of use is not measured. This may or may not be a problem, depending on the situation. For irrigation management purposes, the measurement is fine.

• Siphon flow rates will vary if the water level in the ditch changes. If the water level fluctuates, measurements should be made at several times so the irrigator can approximate an average flow rate.

• The ditch water level may also vary due to field slope. This variation affects the head on each siphon and thus affects the flow. It will then be necessary to select a siphon that is flowing the "average" amount, or several siphons will have to be measured and an average flow rate per siphon determined.

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A-11

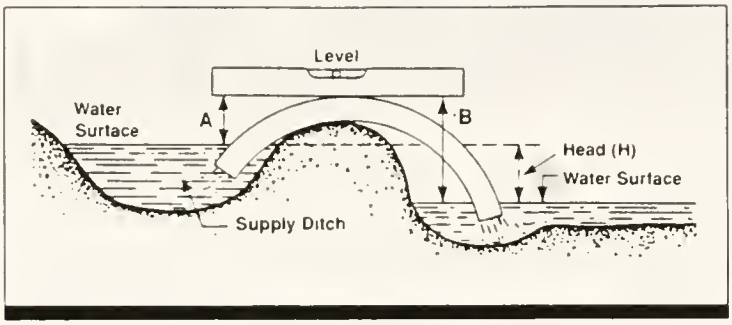

Figure 1. Siphon flow measurement under submerged conditions

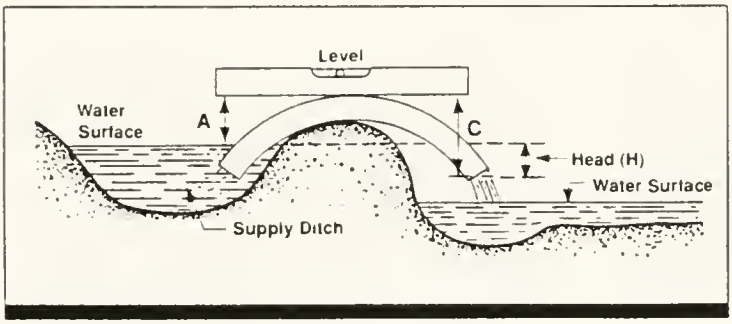

Figure 2. Siphon flow measurement under free flow conditions

Water measurement

The head on a siphon is simply the difference in water elevation from the upstream to the downstream end of the siphon. Two conditions, shown in Figures 1 and 2, are found in the field. In the first situation, the downstream end of the siphon is submerged. In the second condition, the downstream end of the siphon is discharging water into the air. The head can be easily measured by laying a carpenter's level across the top of the ditchbank and measuring down with a tape. In some cases it may be necessary to use a board with the level to span the ditchbank. If the downstream end is submerged, the upstream and downstream water surfaces are the measurement points. If the siphon is discharging freely, the measurement point on the upstream side is the water surface, and on the downstream side it is the center of the siphon. In both cases, the head ("H") is determined by subtracting the upstream measurement ("A") from the downstream measurement ("B" or "C").

Figure 3 gives the flow rate in gallons per minute (gpm) for 3/4-inch to 3-inch siphons at various heads. Figure 4 gives the flow rate in cubic feet per second for 4-inch to 12-inch siphons for various heads. For example, if the head on a 2-inch siphon is four inches, the flow rate is approximately 28 gpm. With 50 siphons operating, the flow rate would equal 28 gpm x 50 siphons or 1,400 gpm.

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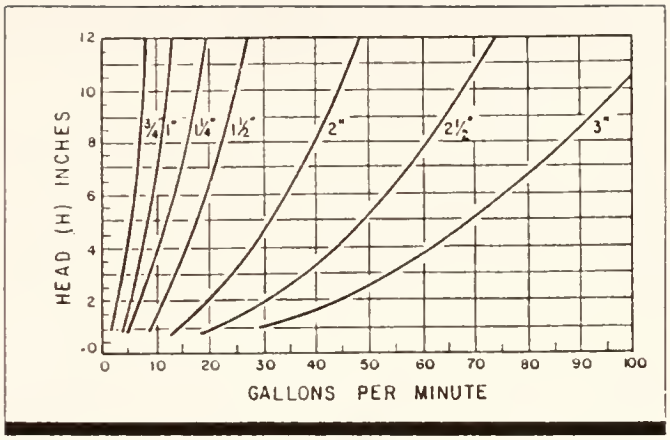

Figure 3. Flow rate vs. head for small siphons

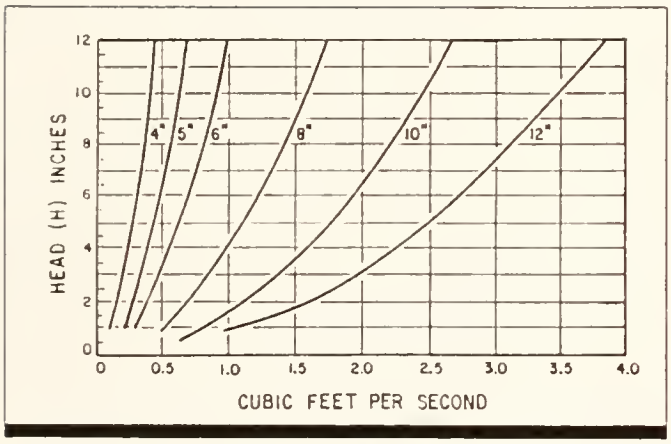

Figure 4. Flow rate vs. head for large siphons

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second x hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute x hours}}{\text{450 x area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches x hours}}{\text{40 x area irrigated in acres}}$$

File under: Water Measurement
A-11 (Devices and Methods)
Issued January 1992 1652000192 MS

Water Measurement

MT 9131 (AG)

Propeller Meters

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

What is a propeller meter?

Propeller meters look somewhat like a ship's propeller and can be placed in pipelines or channels to measure water. Water velocity causes the propeller to turn. By counting the number of turns in a time period and knowing the cross-sectional area where the propeller is placed, the water flow rate can be determined.

Propeller meters are available in several styles. A typical portable propeller meter for use in pipelines is shown in Figure 1. This type of meter is available in sizes ranging from 6 to 36 inches in diameter. Manufacturer's specifications must be consulted to determine the mimimum and maximum flow rates that can be measured by a particular meter. Each meter is calibrated for a specific inside pipe diameter. The meter is held in place by a saddle fixture with U-bolts around the pipe. The saddle fixture can be removed and the meter taken to several sites to check flow rates. A "blank" is used to seal the opening. This type of meter can also be mounted in a short length of pipe, and the entire unit can be carried to different measuring stations.

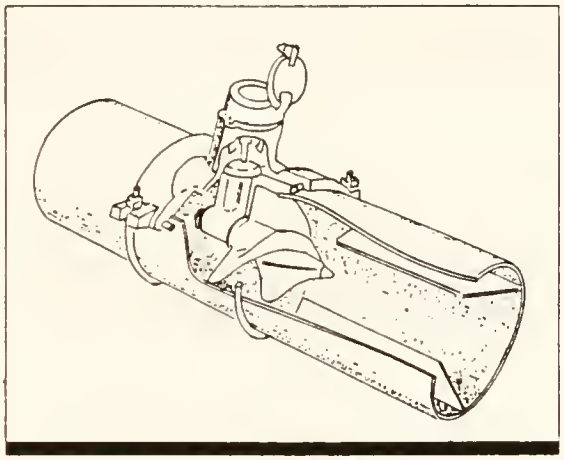

Figure 1. A typical portable propeller meter.

An open flow propeller meter is shown in Figure 2. The meter can be used in various-sized pipes or openings to determine water velocity. These meters in the appropriate make and model can be used in pipes with inside diameters of 10 to 54 inches and with flows ranging from 125 to 36,000 gpm. Stem heights can be specified in 6-inch increments. The open flow propeller meters measure velocity. To measure volume over a period of time the cross

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A-9

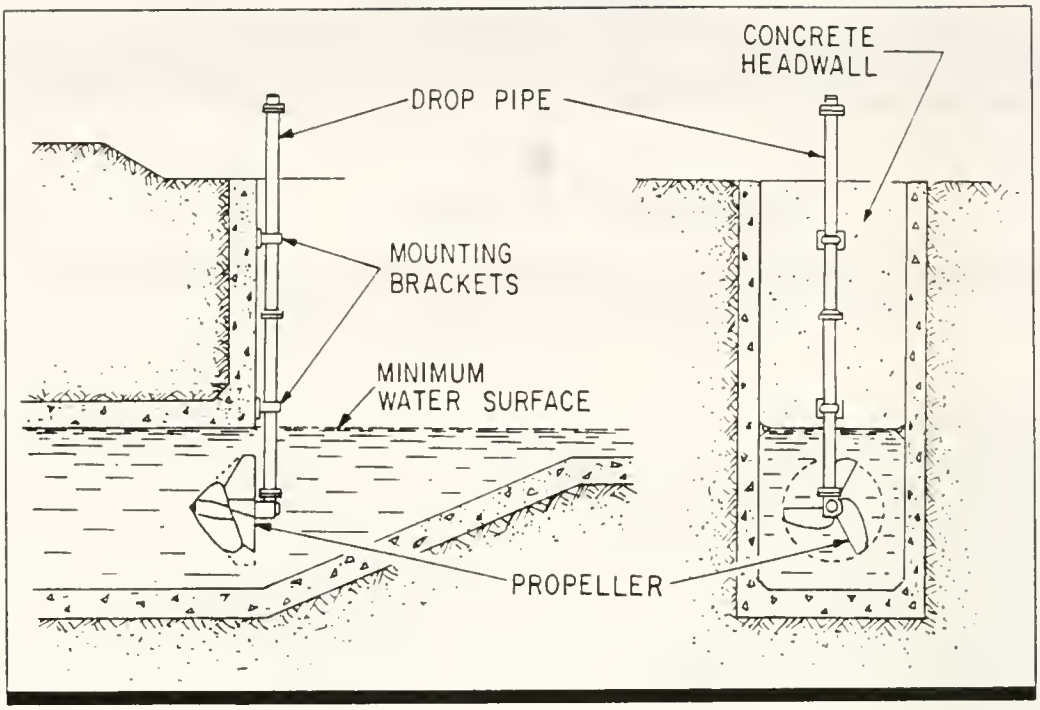

Figure 2. An open flow propeller meter.

sectional area of the pipe or opening must be determined and multiplied by the velocity.

Advantages

• Propeller meters read in units that can be directly used for irrigation management and monitoring of system operation. The readings can be in both velocity and volume. Thus an irrigator can tell what the flow rate is at a particular time and how many acre-feet have been applied to a field.

• Many years of use have led to refined meter design and characteristics.

• One open flow propeller meter can be used at many turnouts. The meter can be slipped into permanently installed brackets. If the cross-sectional area is known and the meter is properly calibrated, volume amounts for a particular time period can be read directly.

• The meters are capable of totalizing flow volumes without auxiliary recorders or calculations.

• Meters are accurate to approximately two percent when properly installed and maintained, and readings should be accepted in any jurisdiction.

Disadvantages

• Meters require periodic maintenance. The gears, bushings, and bearings tend to wear and must be replaced or repaired.

• When used in water carrying debris such as grass or strands of "moss" the meters catch the material and clog or rotate slowly, which results in inaccurate readings. Clogging is less of a problem when the meter is portable and frequently observed. Screening will help protect the meter, but the screens may have to be cleaned carefully and frequently.

• Propeller meters in small sizes cost several hundred dollars and large sizes are very expensive.

Location and Installation

Propeller meters are typically installed in pipelines. The meters can be used only in the pipe size for which they are calibrated. A typical farm turnout with a propeller meter is shown in Figure 3. The outside and inside pipe diameters are critical dimensions, and both must be specified when

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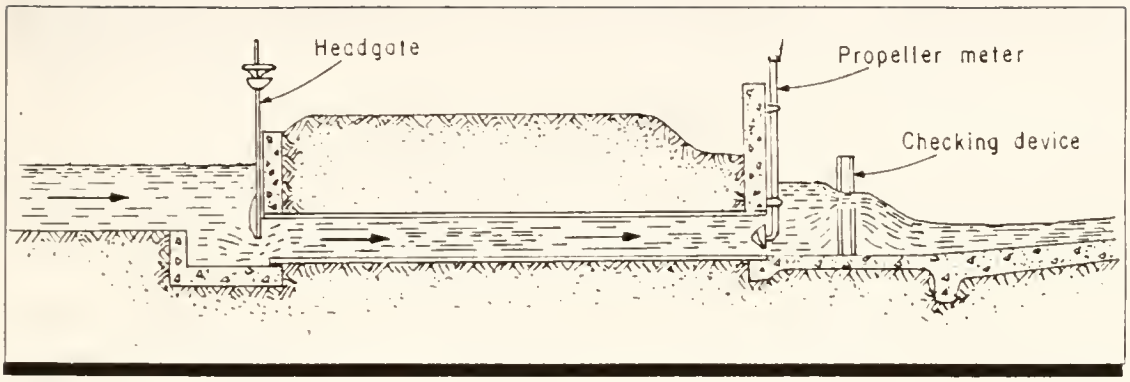

Figure 3. A farm turnout with a propeller meter.

placing an order. The meter should be installed in a section of pipe that is straight upstream for a distance of five to eight pipe diameters, depending on meter size. If turns or obstructions exist, straightening vanes may be required. Provisions must be made for screening out moss or other debris. If the water contains abrasive sediment such as sand or silt, special meter designs may be required. The pipe must flow full of water for accurate readings. The meter should be easy to remove for cleaning, maintenance, and winter storage.

Open flow propeller meters are installed using brackets to which the meter is permanently or temporarily fastened. Manufacturer's specifications must be followed in establishing proper dimensions and clearances. Figure 2 shows representative construction details, but installations can be quite different and help may be needed from a consultant or the Soil Conservation Service to finalize a design.

Meters from different companies are similiar in appearance but do have different features, costs, and specifications. Flow rates read from the meter can be specified in gallons per minute, cubic feet per second, or miner's inches. Volume can be measured and totalized in acre-feet, cubic feet, or gallons. Meters normally can be purchased from dealers handling sprinkler irrigation equipment. Purchase should be based on features as well as price.

Water Measurement

The indicator-totalizer dial on the meter records the measurement. Using the meter is as simple as reading the speedometer (velocity) and odometer (volume) on your car. The meters must be properly installed and maintained so that the readings taken are unquestionably accurate. When properly used and maintained, propeller meters are excellent measuring devices.

Units of Measurement

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Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

File under: Water Measurement
A-9 (Devices and Methods)
Issued February 1992 1692000292 MS

Water Measurement

MT 9126 (AG)

The Metergate

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

What is a metergate?

A metergate is a turnout-control gate which has been calibrated so it can be used to measure water flow. A metergate with stilling wells is shown in Figure 1. The gate is typically attached to a length of corrugated metal pipe or attached with anchor bolts to a concrete headwall and concrete pipe. The gate is commercially manufactured and must be purchased from a dealer. A metergate is relatively simple to install and use, but professional help may be necessary when very large flows are being measured. In considering the use of a metergate as a measuring device the user should evaluate the advantages and disadvantages listed below.

Advantages

- Gates can be used for water control as well as for measurement. Thus only one structure is required rather than the typical headgate and separate measuring device.
- The pipe portion which is an integral part of the gate assembly provides a way to carry water through a ditch bank and also can be used as a road crossing if necessary.
- If the gate is attached to corrugated metal pipe it is relatively easy to move from one place to another as needed.
- The gate and pipe can be purchased as a unit and installation is simple.
- Gates are available in a wide range of sizes ranging from eight inches to 48 inches. This range will accommodate flows from approximately one cubic foot per second to 75 cubic feet per second.
- The gates will measure water accurately with only minimal head loss. A head differential of only two inches is adequate.

Disadvantages

- The gates will pass a different flow rate as either upstream or downstream water levels change. Adjustments in water level and gate openings can be necessary to maintain constant ditch flow rates.
- The seal to prevent leakage is between two cast iron milled surfaces. The gate can leak if this surface is scored or if the gate is damaged or incorrectly operated.

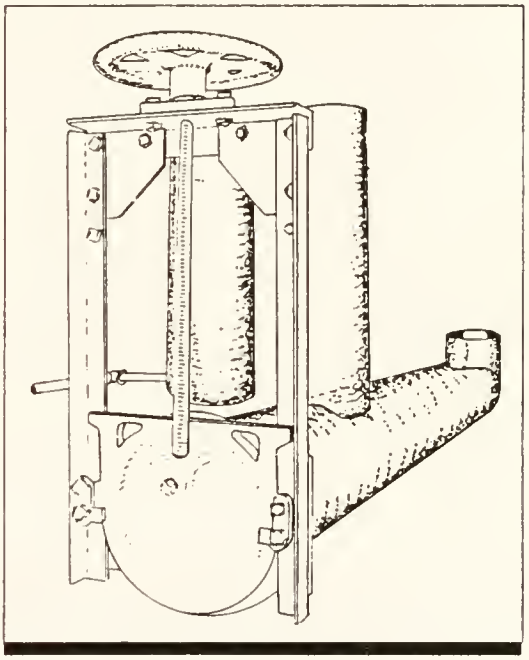

Figure 1. A typical metergate mounted on a corrugated metal pipe.

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A-4

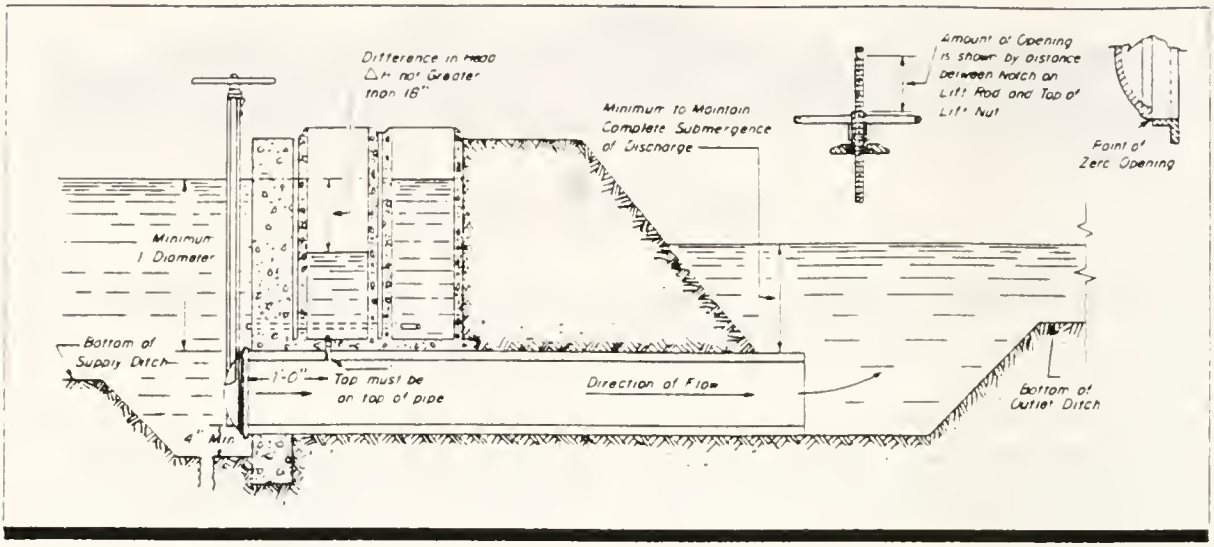

Figure 2. Metergate installation details.

• The gate is very sensitive to plugging by trash and floating debris. This is particularly true when the gate opening is small.

• The maximum head difference that the gates are calibrated for is 18 inches. This may pose a problem in some installations.

Location and construction

A metergate is normally set perpendicular to the flow in the source canal and typically operates as a turnout from a large canal into a lateral or farm ditch. Figure 2 shows some construction details. Notice that the gate and pipe should be set a minimum of four inches above the normal canal bottom. The gate should be installed through a headwall at least three pipe diameters wide made of wood, concrete, or metal. The pipe should be laid on a level grade.

A gate size should be selected to carry the maximum anticipated flow rate. The gate also must fit the ditch. Notice in Figure 2 that it is necessary to have a water depth of at least one pipe diameter above the top of the pipe. This is necessary to prevent pulling air through the main pipe and altering the measurement.

For many irrigation measurements where the upstream water surface is relatively tranquil, the stilling well for the upstream water level can be eliminated and replaced by a reference notch cut into the gate frame. The downstream stilling well is always necessary. It should be set on top of the pipe one foot below the gate. Typically a short length of concrete or metal pipe about eight inches in diameter is used for the downstream stilling well. A hole is made in the top of the main pipe by drilling in a concrete pipe or by using a chisel for corrugated metal pipe. The stilling well is set over the opening and the joint sealed with grout.

The main pipe should be carefully bedded in gravel. It is easiest and best practice to cover the pipe with gravel with a maximum aggregate size of about ¾ inches. The backfill should be placed in about six-inch lifts and tamped. Proper bedding is particularly critical when the pipe is attached to a rigid headwall because any settling by the pipe will break the headwall.

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Two level reference points are established. Measurements are made down from these points to the upstream and downstream water levels. The upstream point can be in a stilling well connected to the upstream water level, or the upstream point can be a notch on the gate frame. The downstream point is in the stilling well connected to the downstream water level. The level reference points can be established with a carpenter's or engineer's level. The reference points can be a saw cut, painted line, or chisel mark. An ordinary pocket metal tape is used to measure from the level reference points down to the water surface.

The last measurement point which must be established is on the lift rod and is used to measure the gate opening. A notch is cut with a hacksaw so that when the notch is level with the top of the wheel the gate opening is zero. As the wheel is turned to open the gate, the notch rises above the wheel. The gate opening is thus from the notch to the top of the wheel.

If the ditch leading away from the pipe is steep, the pipe may not flow full. If this is the case it will be necessary to provide an elbow or structure on the downstream end of the main pipe to back water into the pipe so there is water in the downstream stilling well. An accurate measurement can not be made if the downstream well does not contain water.

Water measurement

The discharge in cubic feet per second (cfs) is shown in Table 1 (see back page) for an 18-inch gate. This size was selected because it is about average and illustrates the type of tables available. Tables are also available from the manufacturer for gate diameters of 8, 10, 12, 14, 15, 16, 18, 20, 21, 24, 30, 36, 42, and 48 inches. The table shows the head in inches compared to the gate opening in inches. The body of the table contains the flow rate. The head is obtained by measuring down from the reference points to the water level on the upstream and downstream side of the gate, then subtracting the downstream reading from the upstream reading. The gate opening is obtained by measuring from the hacksaw mark on the lift rod down to the wheel.

For example, if the upstream reading is 21 inches and the downstream is 28 inches, the difference is seven inches. If the gate size is 18 inches and the gate opening is 10 inches, Table 1 shows that the flow rate is 5.20 cubic feet per second.

Summary

The metergate is an accurate measuring device which is quick and easy to use. It can be used for both water control and measurement, and is adapted to many Montana conditions.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second x hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute x hours}}{450 \text{ x area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches x hours}}{40 \text{ x area irrigated in acres}}$$

DISCHARGE DATA

18" WATERMAN RED TOP CANAL GATES WITH METERING WELLS — MODEL C-10

Head in Inches	Net Gate Opening In Inches																			
	2	2½	3	3½	4	4½	5	5½	6	7	8	9	10	11	12	13	14	15	16	17	18
	Discharge in Cubic Feet Per Second																				
1	.50	.62	.74	.86	.97	1.07	1.17	1.25	1.34	1.54	1.68	1.82	1.95	2.16	2.37	2.51	2.62	2.75	2.86	3.00	3.13
1¼	.56	.69	.83	.95	1.08	1.20	1.31	1.40	1.50	1.72	1.88	2.04	2.20	2.43	2.66	2.79	2.93	3.05	3.20	3.35	3.51
1½	.61	.75	.90	1.04	1.18	1.31	1.44	1.55	1.65	1.88	2.05	2.24	2.41	2.66	2.91	3.05	3.20	3.35	3.51	3.66	3.85
1¾	.67	.83	.98	1.13	1.28	1.42	1.56	1.67	1.78	2.05	2.23	2.43	2.63	2.90	3.17	3.29	3.46	3.62	3.78	3.96	4.13
2	.71	.87	1.03	1.20	1.37	1.52	1.66	1.78	1.90	2.17	2.38	2.58	2.78	3.06	3.35	3.51	3.68	3.87	4.04	4.22	4.40
2¼	.75	.92	1.10	1.27	1.45	1.60	1.75	1.88	2.01	2.31	2.52	2.74	2.95	3.25	3.57	3.74	3.91	4.09	4.29	4.48	4.66
2½	.79	.97	1.16	1.34	1.53	1.69	1.85	1.98	2.12	2.43	2.65	2.87	3.11	3.42	3.75	3.94	4.11	4.31	4.51	4.70	4.92
2¾	.83	1.02	1.21	1.40	1.60	1.77	1.93	2.08	2.22	2.55	2.78	3.02	3.25	3.58	3.92	4.11	4.33	4.53	4.73	4.95	5.18
3	.87	1.07	1.27	1.47	1.68	1.85	2.03	2.19	2.33	2.66	2.91	3.16	3.41	3.76	4.10	4.31	4.51	4.70	4.92	5.18	5.40
3¼	.90	1.11	1.32	1.53	1.75	1.93	2.12	2.27	2.42	2.78	3.03	3.30	3.55	3.91	4.28	4.48	4.66	4.90	5.11	5.37	5.62
3½	.94	1.16	1.37	1.58	1.80	1.99	2.18	2.34	2.50	2.87	3.13	3.40	3.68	4.06	4.45	4.66	4.86	5.08	5.31	5.57	5.81
3¾	.97	1.19	1.42	1.65	1.88	2.08	2.27	2.43	2.60	2.99	3.25	3.53	3.82	4.21	4.60	4.79	5.01	5.27	5.49	5.75	6.00
4	1.00	1.23	1.46	1.69	1.93	2.13	2.35	2.50	2.68	3.07	3.35	3.63	3.93	4.34	4.75	4.97	5.20	5.44	5.68	5.95	6.22
4¼	1.03	1.27	1.50	1.74	1.98	2.19	2.40	2.57	2.75	3.16	3.45	3.75	4.04	4.45	4.86	5.11	5.35	5.62	5.86	6.13	6.40
4½	1.06	1.30	1.55	1.80	2.05	2.26	2.48	2.66	2.85	3.27	3.55	3.86	4.17	4.60	5.03	5.29	5.51	5.77	6.02	6.31	6.57
4¾	1.09	1.33	1.58	1.84	2.10	2.32	2.55	2.73	2.92	3.34	3.65	3.97	4.28	4.72	5.17	5.42	5.66	5.90	6.16	6.46	6.76
5	1.11	1.37	1.63	1.89	2.15	2.38	2.61	2.80	3.00	3.43	3.74	4.08	4.38	4.84	5.30	5.55	5.79	6.09	6.33	6.64	6.93
5½	1.16	1.43	1.70	1.97	2.25	2.48	2.72	2.92	3.13	3.59	3.90	4.25	4.60	5.06	5.52	5.81	6.09	6.35	6.67	6.96	7.29
6	1.22	1.50	1.78	2.08	2.35	2.60	2.85	3.06	3.28	3.77	4.10	4.48	4.80	5.30	5.80	6.11	6.35	6.67	6.96	7.29	7.60
6½	1.27	1.57	1.86	2.15	2.45	2.72	2.98	3.20	3.41	3.92	4.27	4.65	5.00	5.52	6.05	6.33	6.60	6.91	7.22	7.56	7.91
7	1.31	1.61	1.92	2.23	2.55	2.80	3.08	3.26	3.53	4.05	4.43	4.80	5.20	5.74	6.28	6.55	6.87	7.18	7.52	7.87	8.23
7½	1.36	1.67	1.98	2.31	2.63	2.90	3.18	3.42	3.67	4.20	4.60	5.00	5.35	5.92	6.50	6.80	7.09	7.43	7.78	8.16	8.49
8	1.40	1.72	2.05	2.38	2.72	3.01	3.30	3.55	3.78	4.35	4.72	5.15	5.55	6.12	6.68	7.00	7.34	7.67	8.02	8.41	8.76
8½	1.44	1.78	2.11	2.46	2.80	3.10	3.40	3.65	3.89	4.45	4.88	5.30	5.70	6.27	6.85	7.22	7.56	7.94	8.27	8.67	9.00
9	1.48	1.82	2.17	2.52	2.88	3.19	3.50	3.75	4.00	4.60	5.03	5.45	5.90	6.51	7.13	7.43	7.78	8.13	8.49	8.89	9.31
9½	1.53	1.89	2.25	2.61	2.97	3.28	3.60	3.87	4.13	4.74	5.20	5.62	6.10	6.70	7.30	7.60	8.00	8.39	8.71	9.13	9.56
10	1.57	1.93	2.30	2.67	3.04	3.36	3.69	3.95	4.22	4.85	5.30	5.75	6.23	6.86	7.50	7.82	8.18	8.56	8.96	9.40	9.78
11	1.65	2.03	2.41	2.80	3.20	3.54	3.88	4.15	4.43	5.10	5.57	6.05	6.50	7.17	7.85	8.23	8.58	8.98	9.37	9.82	10.24
12	1.72	2.12	2.52	2.92	3.35	3.69	4.05	4.35	4.65	5.30	5.80	6.35	6.87	7.56	8.25	8.56	8.93	9.37	9.78	10.26	10.69
13	1.80	2.21	2.63	3.05	3.46	3.85	4.22	4.52	4.83	5.53	6.05	6.60	7.10	7.82	8.55	8.89	9.33	9.76	10.20	10.67	11.13
14	1.85	2.28	2.71	3.16	3.60	3.97	4.35	4.67	5.00	5.70	6.25	6.80	7.30	8.05	8.80	9.21	9.67	10.11	10.56	11.07	11.55
15	1.93	2.37	2.81	3.26	3.72	4.12	4.51	4.85	5.20	5.90	6.50	7.05	7.65	8.42	9.20	9.56	10.00	10.47	10.91	11.46	11.96
16	1.98	2.44	2.90	3.37	3.85	4.26	4.67	5.01	5.35	6.10	6.70	7.30	7.85	8.62	9.40	9.85	10.29	10.80	11.31	11.80	12.33
17	2.04	2.52	3.00	3.48	3.96	4.38	4.80	5.15	5.50	6.30	6.90	7.50	8.10	8.93	9.75	10.18	10.63	11.13	11.59	12.20	12.89
18	2.11	2.61	3.10	3.59	4.09	4.52	4.95	5.30	5.65	6.50	7.10	7.70	8.30	9.15	10.00	10.45	10.93	11.46	11.98	12.55	13.09

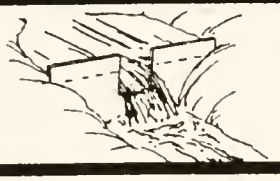
Table 1. Head and gate opening in inches compared to flow rate in cubic feet per second for an 18-inch metergate.

File under: Water Measurement
A-4 (Devices and Methods)
Issued March 1992 1712000392 MS

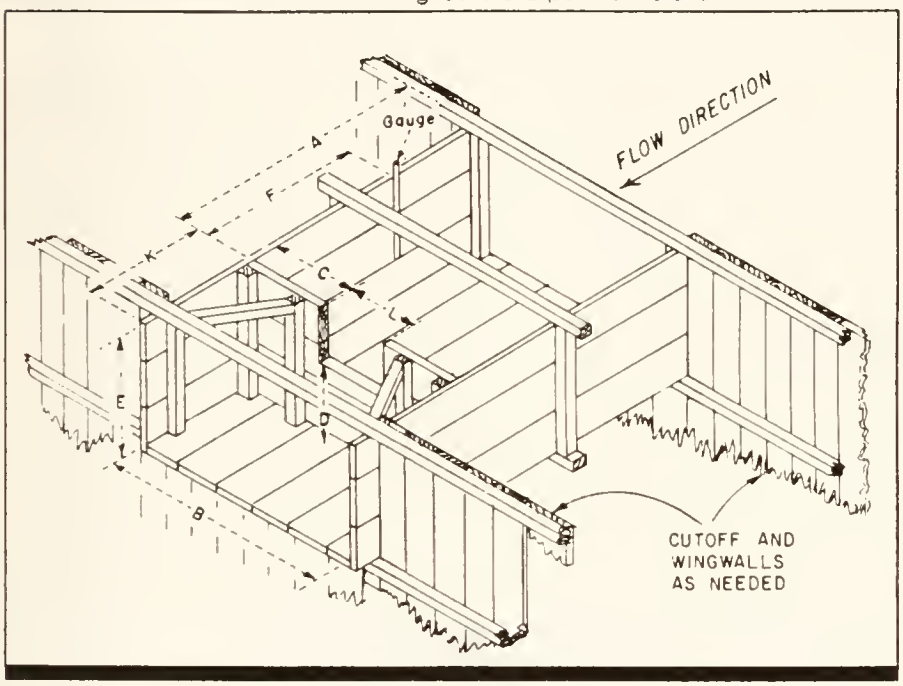
Water Measurement

MT 9123 (AG)

Rectangular Contracted Weirs



Gerald L. Westesen, Professor of Civil and Agricultural Engineering, Agricultural Experiment Station



What is a Weir?

A "weir" is one of the oldest, simplest and most reliable structures for measuring water flow in canals and ditches. A weir's operation is easily observable and improper operation can be readily detected and quickly corrected.

A rectangular contracted weir is an overflow structure built across an open channel. The notch through which the water pours is narrower than the width of the channel and is above the bottom. Other types of weirs may have a different notch shape, or the overpour portion may occupy the full width of the channel. Many people refer to Parshall flumes as weirs. The two devices are completely different in construction and measuring technique.

Dimensions in feet for rectangular contracted weirs

Flow in C.F.S.	L Length of Weir Crest	A Length of Box Above Weir Notch	K Length of Box Below Weir Notch	B Inside Width of Box	E Inside Depth of Box	C End of Crest to Side	D Crest to Bottom	F Gauge Distance Upstream
to 3	1	6	2	5 1/2	3 1/2	2 1/4	2	4
2 to 5	1 1/2	7	3	7	4	2 3/4	2 1/2	4 1/2
4 to 8	2	8	4	8 1/2	4 1/2	3 1/4	2 3/4	5
6 to 14	3	9	5	12	5	4 1/2	3 1/4	5 1/2
10 to 22	4	10	6	14	5 1/2	5	3 1/2	6

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A-1

Water Should Be Measured Because . . .

Water measurement is the foundation of water management and economical crop production. Measuring and applying the proper amount of water saves you money and protects water resources by decreasing soil erosion, fertilizer leaching, and waste water problems.

Montana law requires measuring devices on all streams for which water commissioners have been appointed. A commissioner cannot deliver water unless measuring devices are in place. Eventually all Montana waters will be decreed. You can protect your water right by accurately measuring and recording flow rates and times of use.

Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

Advantages/disadvantages

Weirs will accurately measure water with less than five percent error when carefully installed, maintained and read. Portable weirs can be relocated to spot check flow rates. Weirs do not clog easily, and are simple and relatively inexpensive to build. Because of their accuracy, their readings are accepted by the courts and virtually all agencies.

Careful construction is important or water measurement may not be accurate. Silting-in can be a major problem. Because of the clear overpour required, use will be limited to areas where there is a natural drop, or to channels with a large amount of fall.

Construction

A rectangular contracted weir can be constructed by anyone with fundamental carpentry and/or masonry skills. The base of the notch over which water flows is the weir "crest." The depth of the water flowing over the crest is the "head." Proper dimensions are shown in the chart on the first page of this guide. The length of the weir crest is given in multiples of one foot. For easy water measurement, the lengh of the crest should be an even number of feet. It should be noted that any construction in a natural perennial flowing stream requires an SB 310 permit from the conservation district in that area.

- Use treated rough lumber, concrete, concrete blocks, sheet metal or other durable material.
- Size the weir so that, at maximum flow:
  a) the crest length is about three times the head depth.
  b) the distance from the edge of the notch to the channel sides is at least two times the head depth.
  c) the distance from the channel bottom to the crest is at least three times the head depth.
- Attach a 1/8"-thick metal strip to the crest and sides of the weir.
- Use a cut off wall so water can't go under the weir.
- Provide an underdrain to drain the pool and prevent damage by freezing.

Installation

The weir must be installed and maintained so that its original dimensional relationships remain true.

- Set the weir in a section of the ditch with enough drop so that water can pour freely over the weir's crest.

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft^3), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

- Place the weir where the upstream channel is straight for at least ten times the length of the weir crest.
- Set the weir with the crest perpendicular to the water flow so that it doesn't lean upstream or downstream.
- Ensure that the crest is level so water flowing over it will be the same depth at all points.
- Use cobble or concrete to protect the channel below the weir from erosion.

Maintenance

Weir maintenance, while it is important, is relatively simple. If not properly maintained, the life of the structure will be appreciably shortened and the measurements made will not be accurate. Here are some maintenance tips:

- Clear the channel and weir crest of weeds, trash, and other floating debris.
- Keep the weir pond and bulkhead free of sediment.
- Trim the channel and weir pond of vegetation which interferes with the flow of water.
- Make sure the crest does not settle out of level and that leakage is not occurring through and around the structure.

Water Measurement

Two measurements are used to determine flow in cubic feet per second: head and weir crest length.

Head is normally measured upstream, a distance of at least four times the expected maximum head, so the measurements are not affected by the downward curve of water as it approaches the crest.

Head can be easily measured by driving a stake or establishing a reference point upstream which is level with the weir crest. The distance from the top of the stake to the water surface is the head. Head measurement upstream is often done by setting a staff gauge. Gauges are made of metal and calibrated in tenths and hundreths of feet.

If a stake cannot be set upstream, the head can be measured at the crest by using a board (such as a two-by-four) held edgewise to the flow and resting on the crest. The velocity of the water will cause the water to "climb" the board. The distance from the weir crest to the height to which the water climbs is a good measure of the head.

The other measurement, weir crest length, is constant for each weir. Painting the length of the crest on the structure allows quick reference.

Table 1 (see next page) gives the flow for various heads and crest lengths. The flow is given in cubic feet per second (cfs) and must be multiplied by 40 to obtain Montana Miners Inches (M.I.). For weirs of odd sizes, proportional amounts of the stated lengths can be used with little error. The flow can also be calculated using the formula $Q=3.33\ H^{3/2}\ (L-0.2H)$ where Q is the discharge in cubic feet per second, H is the head, and L is the length of the crest in feet. Convert all measurements to feet before using the formula.

Table 1 is read directly. For a head of .85 feet and a 4.0 foot crest length, the discharge is 10.01 cfs. Muluply this by 40 to give 400.4 Miner's Inches. Most water-users would call this a flowrate of 400 inches.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second x hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute x hours}}{450 \text{ x area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches x hours}}{40 \text{ x area irrigated in acres}}$$

Table 1 Discharge values for rectangular contracted weirs in cubic feet per second

Head in Feet	Discharge, Q, for crest lengths of . . . 1.0 Ft	1.5 Ft	2.0 Ft.	3.0 Ft	4.0 Ft	for each foot in excess of 4 feet
.10	.11	.16	.21	.32	.43	.11
.15	.19	.29	.39	.58	.78	.20
.20	.29	.44	.59	.89	1.20	.30
.25	.40	.61	.82	1.23	1.65	.42
.30	.53	.80	1.07	1.61	2.16	.55
.35	.66	1.00	1.34	2.02	2.71	.69
.40	.80	1.21	1.63	2.46	3.30	.84
.45	.96	1.44	1.94	2.93	3.92	1.00
.50	1.11	1.68	2.26	3.42	4.58	1.16
.55	1.28	1.94	2.60	3.94	5.27	1.34
.60	1.45	2.20	2.96	4.47	6.00	1.52
.65	1.65	2.47	3.32	5.03	6.75	1.71
.70	1.82	2.76	3.70	5.61	7.52	1.91
.75	2.01	3.05	4.10	6.21	8.33	2.12
.80	2.21	3.35	4.51	6.83	9.16	2.33
.85	2.41	3.66	4.92	7.46	10.01	2.55
.90	2.62	3.98	5.35	8.12	10.89	2.78
1.00	3.06	4.64	6.25	9.48	12.72	3.24
1.05	____	4.98	6.71	10.18	13.66	3.49
1.10	____	5.33	7.18	10.90	14.63	3.37
1.15	____	5.69	7.66	11.63	15.62	3.99
1.20	____	6.06	8.16	12.38	16.63	4.25
1.25	____	6.43	8.66	13.15	17.65	4.51
1.30	____	____	____	13.93	18.70	4.78
1.35	____	____	____	14.72	19.77	5.06
1.40	____	____	____	15.53	20.85	5.34
1.45	____	____	____	16.35	21.96	5.62
1.50	____	____	____	17.18	23.08	5.91

File under: Water Measurement
A-1 (Devices and Methods)
Issued October 1991 13320001091MS

Water Measurement

MT 9129 (AG)

The Parshall Flume (Part 1)

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

This bulletin is composed of two parts. Part 1 should be used by those who are choosing among types of measuring devices, or who need information and tables for flume use. Part 1 describes the flume, gives its advantages and disadvantages, and tells how to measure water. Part 2 (MT 9130) gives flume dimensions, describes sizing and locating the flume, and tells how to measure water under submerged condition. Part 2 is quite technical and intended for use by technicians, contractors, and engineers.

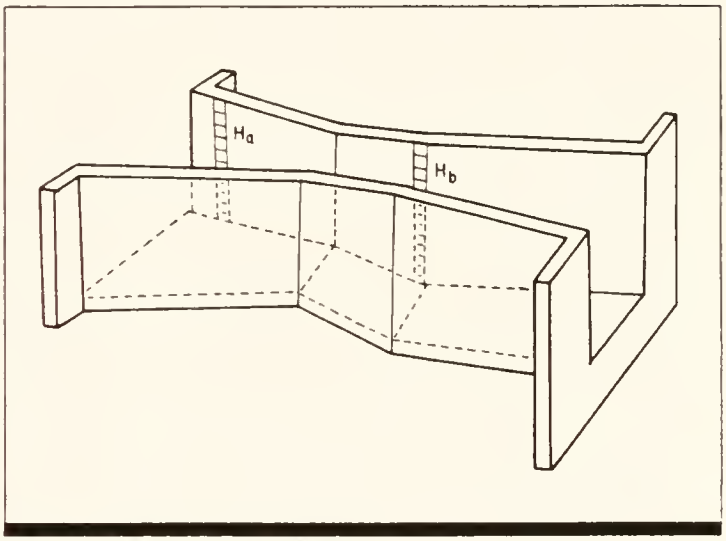

Figure 1. A Parshall measuring flume.

What is a Parshall flume?

A Parshall flume, shown in Figure 1, is a specially shaped structure which can be installed in a channel to measure the water flow rate. The flume was developed and calibrated by Ralph Parshall at Colorado State University early in this century and has been used extensively in Montana and other states. Many people confuse the Parshall flume with weirs. Flumes and weirs are not the same. They should not be confused in discussion or when using tables to determine flow rates. Parshall flumes are difficult devices to set and build. They are, however, an accepted and widely used measuring device. Standard-size commercially made flumes are available and in most situations should be selected over on-site construction unless an experienced contractor is available.

Depth Applied to a Field in Inches

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$$= \frac{\text{flow in gallons per minute} \times \text{hours}}{450 \times \text{area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches} \times \text{hours}}{40 \times \text{area irrigated in acres}}$$

The Parshall flume consists of a converging section, the throat (crest), a downward sloping floor, and a rising/diverging downstream section. A short Parshall, also called a Montana flume (discussed in MT 9127 and MT 9128), has only the converging section and crest. The Montana flume cannot be used to measure submerged flow. The portion of the Parshall flume downstream from the crest minimizes erosion and allows measurement when the flow

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A-7

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Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

is partially submerged (when water is "backed up" into the throat). The flume size corresponds to the throat width which normally is in one-foot increments.

Advantages

• The flume can operate with small head loss which allows use in flatter ditches than a weir.

• The flume is relatively insensitive to the velocity of the inflowing water. Thus it can be located in canals and ditches without a stilling pond immediately upstream.

• Fairly good measurements can be obtained under moderate or even considerable submergence when the proper correction factors are used. Remember, submergence should be avoided by proper installation if at all possible. Measurement under submerged conditions is discussed in Part 2 (MT 9130).

• The water velocity through the flume is high enough to virtually eliminate sediment deposition.

• Prefabricated flumes ready for field installation in sizes ranging from one to four feet are available at commercial outlets.

• Accuracy is plus or minus percent if the flume is carefully constructed, and the flume is accepted as an accurate measuring device in virtually all jurisdictions.

• The flume can be built in different sizes to accommodate a wide range of flow rates. Sizes and dimensions are given in Part 2, (MT 9130).

Disadvantages

• The flume requires meticulous attention to detail in construction. Proper dimensions must be followed exactly if the flume is to measure accurately.

• The flume must be set and located correctly for good measurement. Part 2 (MT 9130) gives details on locating and setting the flume.

• The flume cannot be used to control the flow of water. A separate headgate is required.

• Construction and installation is beyond the capabilities of the average water user. Prefabricated flumes are available but help in installation may still be needed.

Water measurement

Tables are available which are used to convert linear measurements to flow. The steps for using a table to determine the flow rate through a Parshall flume are:

1. Determine the flume size. The size is the width at the narrowest part. This part is the throat or crest of the flume.

2. Measure the upstream head, H_a. H_a is measured two-thirds of the distance from the crest to the flume entrance. For most irrigation measurements, a staff gage attached to the flume wall at this point is satisfactory. When precise measurement is required, stilling wells (a pipe set outside the flume but connected to the water in the flume) should be installed so that minor water fluctuations are dampened.

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft^3), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

Head, H_a (feet)	Discharge, Q, for throat widths, W, of__								
	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
0.10	0.11	0.15	——	——	——	——	——	——	——
.15	.20	.30	0.42	0.61	——	——	——	——	——
.20	.35	.51	.66	.97	1.26	1.55	——	——	——
.25	.49	.71	.93	1.37	1.80	2.22	2.63	3.02	3.46
.30	.64	.94	1.24	1.82	2.39	2.96	3.52	4.08	4.62
.35	.80	1.19	1.57	2.32	3.06	3.78	4.50	5.22	5.93
.40	.99	1.47	1.93	2.86	3.77	4.68	5.57	6.46	7.34
.45	1.19	1.76	2.32	3.44	4.54	5.63	6.72	7.80	8.87
.50	1.39	2.06	2.73	4.05	5.36	6.66	7.94	9.23	10.5
.55	1.62	2.39	3.17	4.70	6.23	7.74	9.25	10.8	12.2
.60	1.84	2.73	3.62	5.39	7.15	8.89	10.6	12.4	14.1
.65	2.08	3.09	4.11	6.12	8.11	10.1	12.1	14.1	16.0
.70	2.33	3.46	4.60	6.86	9.11	11.4	13.6	15.8	18.0
.75	2.58	3.85	5.12	7.65	10.2	12.7	15.2	17.7	20.1
.80	2.85	4.26	5.66	8.46	11.3	14.0	16.8	19.6	22.4
.85	3.12	4.67	6.22	9.30	12.4	15.5	18.5	21.6	24.6
.90	3.41	5.10	6.80	10.2	13.6	16.9	20.3	23.7	27.0
.95	3.70	5.55	7.39	11.1	14.8	18.4	22.1	25.8	29.5
1.00	4.00	6.00	8.00	12.0	16.0	20.0	28.0	32.0	
1.10	4.62	6.95	9.27	13.9	18.6	23.3	27.9	32.6	37.3
1.15	4.94	7.44	9.94	14.9	19.9	25.0	30.0	35.0	40.1
1.20	5.28	7.94	10.6	16.0	21.3	26.7	32.1	37.5	42.9
1.25	5.62	8.46	11.3	17.0	22.8	28.5	34.3	40.0	45.8
1.30	5.96	8.99	12.0	18.1	24.2	30.3	36.5	42.6	48.8
1.35	6.32	9.52	12.7	19.2	25.7	32.2	38.7	45.3	51.8
1.40	6.68	10.1	13.5	20.3	27.2	34.1	41.1	48.0	55.0
1.45	7.04	10.6	14.2	21.5	28.8	36.1	43.4	50.8	58.1
1.50	7.41	11.2	15.0	22.6	30.3	38.1	45.8	53.6	61.4
1.55	7.80	11.8	15.8	23.8	32.0	40.1	48.3	56.5	64.7
1.60	8.18	12.4	16.6	25.1	33.6	42.2	50.8	59.4	68.1
1.65	8.57	13.0	17.4	26.3	35.3	44.3	53.3	62.4	71.6
1.70	8.97	13.6	18.2	27.6	37.0	46.4	56.0	65.5	75.1
1.75	9.38	14.2	19.0	28.8	38.7	48.6	58.6	68.6	78.7
1.80	9.79	14.8	19.9	30.1	40.5	50.8	61.3	71.8	82.3
1.85	10.2	15.5	20.8	31.5	42.2	53.1	64.0	75.0	86.0
1.90	10.6	16.1	21.6	32.8	44.1	55.4	66.8	78.2	89.8
1.95	11.1	16.7	22.5	34.1	45.9	57.7	69.6	81.6	93.6
2.00	11.5	17.4	23.4	35.5	47.8	60.1	72.5	84.9	97.5
2.05	11.9	18.1	24.3	36.9	49.7	62.5	75.4	88.4	101.4
2.10	12.4	18.8	25.3	38.4	51.6	64.9	78.4	91.8	105.4
2.15	12.8	19.5	26.2	39.8	53.5	67.4	81.4	95.4	109.5
2.20	13.3	20.2	27.2	41.3	55.5	69.9	84.4	98.9	113.6
2.25	13.7	20.9	28.1	42.7	57.5	72.4	87.5	102.6	117.8
2.30	14.2	21.6	29.1	44.2	59.6	75.0	90.6	106.2	122.0
2.35	14.7	22.4	30.1	45.7	61.6	77.6	93.8	110.0	126.3
2.40	15.2	23.0	31.1	47.3	63.7	80.3	97.0	113.7	130.7
2.45	15.6	23.8	32.1	48.8	65.8	82.9	100.2	117.6	135.1
2.50	16.1	24.6	33.1	50.4	67.9	85.6	103.5	121.4	139.5

Table 1. Free-flow discharge values for Parshall flumes in cubic feet per second.

3. Table 1 gives the free-flow discharge rate for one 1- to eight-foot flumes for upstream heads in 0.05 foot increments. The figures can be interpolated when accuracy requires gage readings to 0.01 feet, or extended tables can be obtained. For example, the discharge rate through a two-foot flume with an H_a reading of 1.10 feet is 9.27 cubic feet per second.

4. If there is any question as to whether the flume is submerged, measure the downstream head (H_b). Locate the H_b gage as shown in Figure 1. For one- to eight-foot flumes this gage point is located two inches upstream and three inches above the lowest part of the flume. The zero point for the gage, however, is at the crest elevation even though the gage point is downstream from the crest. Because the flume's throat section is turbulent, a stilling well should be installed at H_b if submergence is common.

5. Check for submergence by dividing H_b by H_a to obtain a percent submergence value. The flume size (followed by this value in parentheses) is: 1 (62), 1.5 (64), 2 (66), 3 (68), 4 (70), 5 (72), 6 (74), 7 (76), and 8 (78). If the given value is exceeded, the flume is submerged and the free flow discharge rate must be corrected. Seek help or follow the correction procedure given in Part 2, (MT 9130).

Summary

A Parshall flume is an excellent measuring device which has stood the tests of time and use. The flume is difficult to properly locate and construct. Water users should consider obtaining assistance from a qualified specialist or the Soil Conservation Service. When correctly built and located it will measure accurately. The flume is capable of measurement under minimal submerged conditions, but readings must be corrected. If possible the flume should be located and set to operate in a non-submerged condition.

File under: Water Measurement
A-7 (Devices and Methods)
Issued February 1992 1722000292 MS

Water Measurement

MT 9130 (AG)

The Parshall Flume (Part 2)

Gerald L. Westesen, Professor of Civil and Agricultural Engineering, Agricultural Experiment Station

This portion of the Parshall flume bulletin gives flume dimensions, describes sizing and locating the flume, and tells how to measure water under submerged conditions. This information is quite technical and intended for use by technicians, contractors, and engineers. For a general description of the Parshall flume and its uses see Part 1, MT 9129.

Flume shape and dimensions

A Parshall flume is shown in Figure 1. The flume consists of a converging section, the throat (crest), a downward sloping floor, and a rising/diverging downstream section. Section and plan views are shown in Figure 2. A short Parshall, also called a Montana flume (discussed in MT 9127 and MT 9128), has only the converging section and crest. The portion of the Parshall flume downstream from the crest minimizes erosion and allows measurement when the flow is partially submerged (when water is "backed up" into the throat). The flume size is designated by the throat width which normally is in one-foot increments.

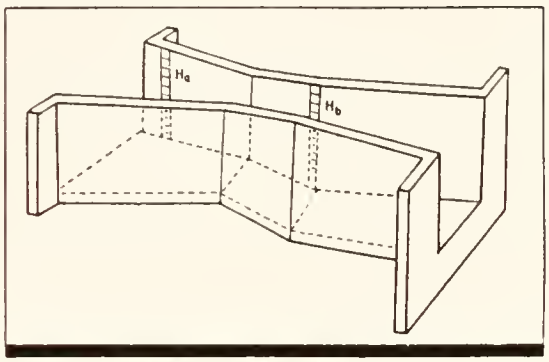

Figure 1. A Parshall measuring flume.

Throat Width	A	B	C	D	Flow rate, cfs Min.	Max.
1 ft	2 ft 9¼ in	2 ft	4 ft 6 in	4 ft 4⅞ in	.11	16.1
1.5ft	3ft 4⅜in	2ft 6in	4ft 9in	4ft 7⅛in	.15	24.6
2ft	3ft 11½in	3ft	5 ft	4ft 10⅞in	.42	33.1
3ft	5ft 1⅞in	4ft	5ft 6in	5ft 4¾in	.61	50.4
4ft	6ft 4¼in	5ft	6ft	5ft 10⅝in	1.3	67.9
5ft	7ft 6⅝in	6ft	6ft 6in	6ft 4½in	1.6	85.6
6ft	8ft 9in	7ft	7ft	6ft 10⅜in	2.6	103.5
7ft	9ft 11⅜in	8ft	7ft 6in	7ft 4¼in	3.0	121.4
8ft	11ft 1⅜in	9ft	8ft	7ft 10⅛in	3.5	139.5

Table 2. Parshall flume dimensions for various throat widths and flow capacities.

Table 2 gives dimensions for various size flumes and corresponding flows. The letter designations in Table 2 correspond to those in Figure 2. Other dimensions shown in Figure 2 that remain the same for all flume sizes in Table 2 are: X=2 in., K and Y =3 in., H=9 in., E=2 ft., F=3 ft., and G=3 ft. or less depending on the required capacity and flow depth.

Locating and sizing the flume

Choosing a location and size for a Parshall flume is difficult. Seek professional help unless you are trained and experienced in flume installation. A large flume can cost thousands of dollars to build and be

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virtually impossible to move if set improperly. Prefabricated metal flumes up to three or four feet in size can be moved and reset but this takes time and labor. The following should be considered in locating a flume.

• Locate the flume in a straight section of channel so the water will flow smoothly into the converging section.

• Locate the flume where it will not be submerged by backwater from downstream. If submergence can not be avoided, make sure it will not be greater than allowed in the correction tables which follow.

• Provide for easy accessibility for maintenance and measurement.

The most difficult aspect of flume location is setting the flume at the proper height in relation to the ditch bottom and banks. The flume is an obstruction in the channel and causes a rise in the water elevation upstream. The banks must be high enough so that they will not be overtopped. Submerged (backed up) flows can be measured if submergence is not complete, but it is best to avoid them. Choosing a good location and setting the flume at the proper height above the ditch bottom will help avoid submergence.

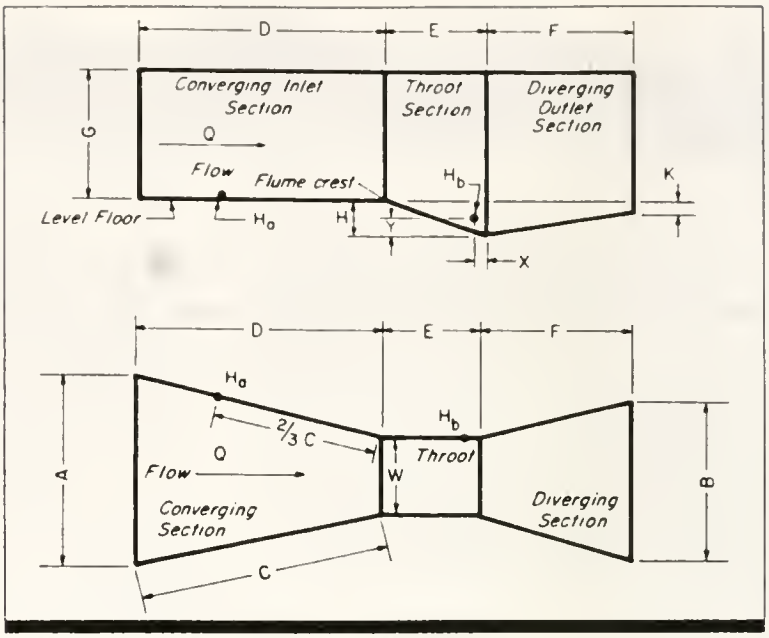

Figure 2. Section and plan views of a Parshall flume.

A flume is considered submerged when the downstream head (water depth) called H_b is a certain percentage of the upstream head (water depth) which is called H_a. These points are shown in Figure 2. The allowable percent value depends on the size (throat width) of the flume. For various size flumes the submergence values of H_b/H_a expressed as a percent and indicated in parentheses are: 1 (62), 1.5 (64), 2 (66), 3 (68), 4 (70), 5 (72), 6 (74), 7 (76), and 8 (78). In other words, a particular size flume should preferably be set so that the water does not back up into the downstream section to a depth greater than the submergence percentage multiplied by the upstream head. On flat ditches the flume may have to be set so that it ordinarily measures in a submerged condition. If this is the case the tabulated values from Table 1 (MT 9129) will have to be multiplied by a correction factor.

The flume size, flow rate, and maximum value of H_a are interrelated. As a general rule the flume size should be about 40 percent of the channel width. Several flume sizes may work in a given setting so several trials may be necessary to choose the best size. It is much easier to make these trials on paper than with steel or concrete. Figure 3 depicts the relationships of flow depths through a Parshall flume and shows an example.

These are the steps in analyzing how the flume should be set:

1. Determine the approximate maximum channel discharge in cubic feet per second.

2. Estimate the desired flume size based on the flow rate and ditch dimensions.

Water Should Be Measured Because . . .

Water measurement is the foundation of water management and economical crop production. Measuring and applying the proper amount of water saves you money and protects water resources by decreasing soil erosion, fertilizer leaching, and waste water problems.

Montana law requires measuring devices on all streams for which water commissioners have been appointed. A commissioner cannot deliver water unless measuring devices are in place. Eventually all Montana waters will be decreed. You can protect your water right by accurately measuring and recording flow rates and times of use.

Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft^3), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

3. Determine the depth at the maximum flow in the ditch or canal by inspecting the banks or from canal specifications.

4. From Table 2 determine the upstream head (H_a) at the maximum discharge rate. A correction factor for submergence (discussed in the water measurement section of this bulletin) may be necessary.

5. Determine the allowable submergence percentage for the desired flume size. If a greater submergence percentage is being allowed because of site conditions such as a flat ditch, estimate this submergence value and use it in further calculations.

6. Multiply the maximum upstream head (H_a) by the submergence percentage to determine the distance the flume crest should be set below the original maximum flow depth.

7. Subtract the distance calculated in step 6 from the original flow depth to determine the height of the flume floor above the channel bottom.

8. Subtract the distance calculated in step 6 from the upstream head (H_a). Add the result to the original flow depth to calculate the rise in upstream water level after the flume is installed. Verify that the banks upstream can handle this increased depth.

This analysis is reiterated in the following example. Again, refer to Figure 3.

Steps 1, 2, 3. Suppose you are considering a two-foot flume, a maximum discharge of 27.0 cubic feet per second, and an original flow depth of 2.5 feet.

Step 4. Using Table 1 (Part 1) and interpolating, for a two-foot flume with a discharge of 27.0 cubic feet per second H_a equals 2.19 feet.

Step 5. To prevent submergence for a two-foot flume the allowable submergence ratio is 66 percent. Use an alternative submergence ratio if some degree of submergence is being allowed.

Step 6. Thus the flume crest (flume floor) should be set below the original maximum flow depth an amount equal to 2.19 x 0.66 or 1.45 feet. (Use the alternative submergence ratio if some degree of submergence is being allowed.)

Step 7. Subtract 1.45 feet (or an alternative value) from the original flow depth of 2.5 feet to determine that the crest floor should be 1.05 feet above the channel bottom.

Step 8. The increase in flow depth upstream of the flume is 2.19 feet minus 1.45 feet or 0.74 feet. The water flowing at a 2.5 foot depth upstream of the flume prior to installation will rise 0.74 feet to flow at a depth of 3.24 feet after installation. The banks upstream must be able to handle this greater water depth. Allowing greater flume submergence will decrease the upstream flow depth.

Several size flumes can carry the 27.0 cubic feet per second flow rate used in this example. These sizes should be evaluated before construction to see which size would best fit the ditch and situation. The narrowest flume may not always be the most economical because of the wing wall length needed to span the channel and the increased

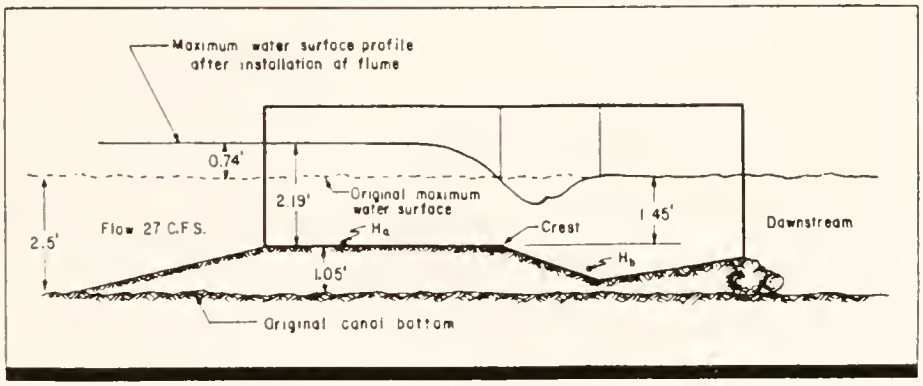

Figure 3. Analysis of upstream and downstream water elevations and crest elevation above the channel bottom.

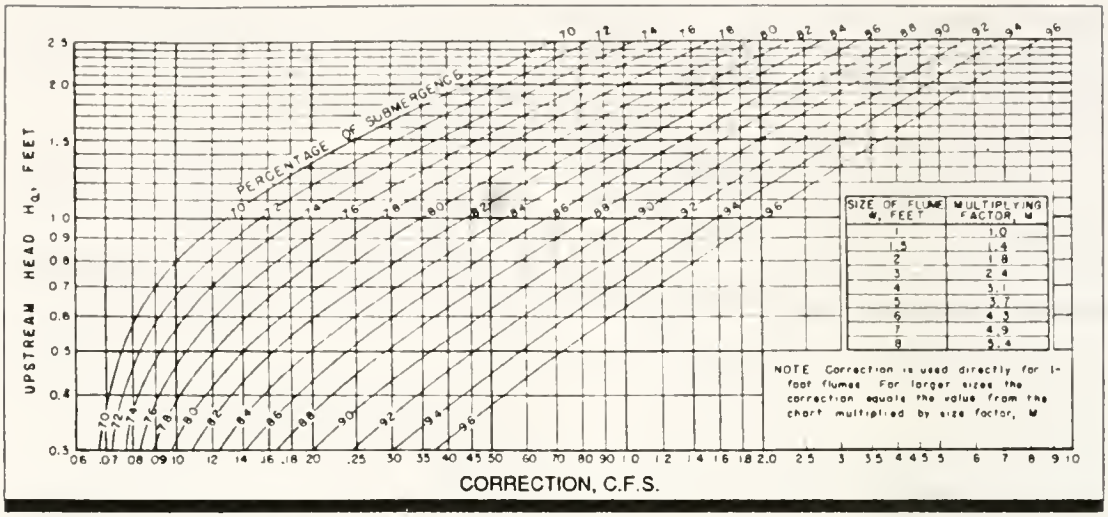

Figure 4.Diagram for determining correction to be subtracted from free-discharge flow to obtain rate of submerged flow through Parshall flumes one to eight fee wide.

upstream water depth. In some situations it will be impossible or too expensive to select a flume which will not submerge. In these cases the above analysis should be done with some percent submergence allowed, and the submergence compensated for during measurement. Correction factors for submergence are discussed in the water measurement section which follows.

Building a flume

Flume dimensions are shown in Figure 2 and Table 2. These dimensions must be followed exactly during construction for water measurements to be accurate. All dimensions given are inside measurements. Prefabricated sheet metal flumes have the advantage of in-shop construction where pieces can be properly jigged and bent or welded. This is difficult in a farm shop when generally only one flume is built. Prefabricated flumes are the best choice for small sizes. Flumes built in place are generally cheaper for larger sizes.

Flumes of treated lumber or concrete can be built in place. The flume floor should be level and the sides should be plumb. The form work required for concrete flumes should only be done by careful, experienced workers. Concrete flumes need steel reinforcement. If a contractor is hired, he should be required to guarantee exact dimensions and good workmanship.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second} \times \text{hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute} \times \text{hours}}{450 \times \text{area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches} \times \text{hours}}{40 \times \text{area irrigated in acres}}$$

Measuring submerged flow

If it appears the flume may be submerged, check for submergence by dividing H_b by H_a and comparing the result against the submergence value for particular size flume that was noted previously. If the flume is submerged the free flow discharge rate must be corrected. Correction values are given in Figure 4.

Figure 4 is used by entering the figure at the H_a value. Read across to the right to the percentage of submergence determined previously. Read the correction for a one-foot flume on the lower scale. Subtract this correction (or a size-modified correction) from the flow rate for an unsubmerged condition. For example, if a two-foot flume has an H_a reading of 1.1 feet and an H_b reading of 0.9 feet, the submergence is 0.9/1.1 or 82 percent. The discharge table in MT 9129 shows that for the 1.1 foot H_a reading for a two-foot flume the free-flow discharge is equal to 9.27 cubic feet per second. From Figure 4 the correction factor for 82 percent submergence and a 1.1 foot head is 0.52 cubic feet per second. Multiply 0.52 cubic feet per second by the correction factor for a two-foot flume, which is 1.8, to give 0.94 cubic feet per second. The true flow rate under this submerged condition is 9.27 - 0.94 or 8.33 cubic feet per second. If a flume often submerges, submergence tables for that particular flume size can be obtained from the Soil Conservation Service or Department of Natural Resources and Conservation to ease this calculation.

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A-8 (Devices and Methods)
Issued February 1992 1752000292 MS

Water Measurement

MT 9127 (AG)

Montana (Short Parshall) Flume (Part 1)

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

This bulletin is composed of two parts. Part 1 should be used by those making a choice of measuring device, or who need information and tables for flume use. Part 1 describes the flume, gives its advantages and disadvantages, briefly discusses building a flume, and tells how to measure water. Part 2 (MT 9128) gives flume dimensions, and describes sizing, locating and building the flume. Part 2 is quite technical and intended for use by technicians, contractors, and engineers.

What is a Montana flume?

A Montana flume, shown in Figure 1, is a specially shaped structure that can be installed in a channel to measure the water flow rate.

The form of a Montana flume is the same as the converging section of a regular Parshall flume (discussed in MT 9129). It is simpler and handier than a Parshall flume, but is not adapted to as wide a range of conditions and will not measure submerged flow. Information to help decide whether a Montana or a regular Parshall flume is needed follows. Both flumes have been used extensively in Montana and other Western states. Many people confuse the Montana and Parshall flumes with weirs. Flumes and weirs are not the same. They should not be confused in discussion or when choosing tables to determine flow rates.

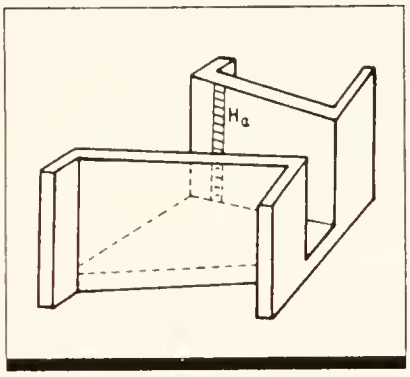

Figure 1. A typical Montana flume.

The Montana flume consists of a converging section and a throat also called a crest. The flume size corresponds to the crest width and is normally in one-foot increments.

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Section and plan views are shown in Figure 2 (Part 2, MT 9128). Montana flumes do not protect the channel downstream of the crest from erosion and can not measure partially submerged flows as the Parshall flume can.

Advantages

• The flume can operate with small head loss which allows use in flatter ditches than a weir. Locaung and setting the flume is discussed in Part 2 (MT 9128).

• The flume is relatively insensitive to the velocity of the inflowing water. Thus it can be located in canals and ditches without a stilling pond immediately upstream.

• The water velocity through the flume is high enough to virtually eliminate sediment deposition.

• Accuracy is plus or minus three percent if the flume is carefully constructed, and the flume is accepted as an accurate measuring device in virtually all jurisdictions.

• The flume can be built in different sizes to accommodate a wide range of flow rates. Flume dimensions are given in Part 2 (MT 9128).

• The simple shape of the flume makes it easy to construct.

Disadvantages

• The flume cannot be used to control the flow of water. A separate headgate is required.

• The flume can not be used for measurement if it is submerged. Under submerged conditions water is not falling smoothly over the crest. The water is "backed up" from downstream.

• The structure does not provide erosion protection.

Locating the flume

Finding a suitable location for and determining the proper size Montana flume to install is easy as long as there is a place where free flow (non-submerged) conditions exist. Many canals or ditches have a natural drop or steep spot. These conditions are ideal for a Montana flume. If it appears that submerged conditions exist or could develop, another location should be selected. If you are having problems with locating or sizing a flume, seek help.

Although not as costly as a Parshall flume, a large Montana flume can cost thousands of dollars to build and be virtually impossible to move. Prefabricated metal flumes up to three or four feet in size can be moved and reset but this takes time and labor.

Building a flume

A Montana flume can be built by anyone with reasonable carpentry skills. Flume dimensions are given in Part 2, (MT 9128). These dimensions are critical and must be followed exactly. Prefabricated metal flumes are the best choice for flumes with a throat width of one to four feet.

Many fabricators only make the Parshall flume. You may be able to have the Montana flume built by special order. For sizes greater than four feet the best choice is to build the flume in place out of treated lumber or concrete.

Careful construction is required. The floor should be level and the sides should be plumb. Adequate steel reinforcement should be used. The form work for the Montana flume is relatively simple and can be done by anyone with reasonable carpentry skills. The work cannot be sloppy, however, and any contractor engaged should be required to guarantee exact dimensions and good workmanship.

The Montana flume usually requires erosion protection downstream from the crest because the water pours through freely and rapidly. A concrete apron, cobble, or other material can be used below the flume. An eddy will develop on each side of the streamflow and erosion protection may be required (depending on the stability of the bank material). Wing walls may be required on the upstream end.

Water measurement

A table can be used to convert linear measurements to flow rate. The steps for using a table to determine the flow rate through a Montana flume are:

1. Determine the flume size. The size is the width at the narrowest part which is the throat or crest of the flume.

2. Inspect the water flow through the throat. If downstream conditions have caused the water to back up and submerge the flow, the measurement will be inaccurate. A

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft^3), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

Head, H_a (feet)	Discharge, Q, for throat widths, W, of__								
	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
0.10	0.11	0.15	—	—	—	—	—	—	—
.15	.20	.30	0.42	0.61	—	—	—	—	—
.20	.35	.51	.66	.97	1.26	1.55	—	—	—
.25	.49	.71	.93	1.37	1.80	2.22	2.63	3.02	3.46
.30	.64	.94	1.24	1.82	2.39	2.96	3.52	4.08	4.62
.35	.80	1.19	1.57	2.32	3.06	3.78	4.50	5.22	5.93
.40	.99	1.47	1.93	2.86	3.77	4.68	5.57	6.46	7.34
.45	1.19	1.76	2.32	3.44	4.54	5.63	6.72	7.80	8.87
.50	1.39	2.06	2.73	4.05	5.36	6.66	7.94	9.23	10.5
.55	1.62	2.39	3.17	4.70	6.23	7.74	9.25	10.8	12.2
.60	1.84	2.73	3.62	5.39	7.15	8.89	10.6	12.4	14.1
.65	2.08	3.09	4.11	6.12	8.11	10.1	12.1	14.1	16.0
.70	2.33	3.46	4.60	6.86	9.11	11.4	13.6	15.8	18.0
.75	2.58	3.85	5.12	7.65	10.2	12.7	15.2	17.7	20.1
.80	2.85	4.26	5.66	8.46	11.3	14.0	16.8	19.6	22.4
.85	3.12	4.67	6.22	9.30	12.4	15.5	18.5	21.6	24.6
.90	3.41	5.10	6.80	10.2	13.6	16.9	20.3	23.7	27.0
.95	3.70	5.55	7.39	11.1	14.8	18.4	22.1	25.8	29.5
1.00	4.00	6.00	8.00	12.0	16.0	20.0	28.0	32.0	
1.10	4.62	6.95	9.27	13.9	18.6	23.3	27.9	32.6	37.3
1.15	4.94	7.44	9.94	14.9	19.9	25.0	30.0	35.0	40.1
1.20	5.28	7.94	10.6	16.0	21.3	26.7	32.1	37.5	42.9
1.25	5.62	8.46	11.3	17.0	22.8	28.5	34.3	40.0	45.8
1.30	5.96	8.99	12.0	18.1	24.2	30.3	36.5	42.6	48.8
1.35	6.32	9.52	12.7	19.2	25.7	32.2	38.7	45.3	51.8
1.40	6.68	10.1	13.5	20.3	27.2	34.1	41.1	48.0	55.0
1.45	7.04	10.6	14.2	21.5	28.8	36.1	43.4	50.8	58.1
1.50	7.41	11.2	15.0	22.6	30.3	38.1	45.8	53.6	61.4
1.55	7.80	11.8	15.8	23.8	32.0	40.1	48.3	56.5	64.7
1.60	8.18	12.4	16.6	25.1	33.6	42.2	50.8	59.4	68.1
1.65	8.57	13.0	17.4	26.3	35.3	44.3	53.3	62.4	71.6
1.70	8.97	13.6	18.2	27.6	37.0	46.4	56.0	65.5	75.1
1.75	9.38	14.2	19.0	28.8	38.7	48.6	58.6	68.6	78.7
1.80	9.79	14.8	19.9	30.1	40.5	50.8	61.3	71.8	82.3
1.85	10.2	15.5	20.8	31.5	42.2	53.1	64.0	75.0	86.0
1.90	10.6	16.1	21.6	32.8	44.1	55.4	66.8	78.2	89.8
1.95	11.1	16.7	22.5	34.1	45.9	57.7	69.6	81.6	93.6
2.00	11.5	17.4	23.4	35.5	47.8	60.1	72.5	84.9	97.5
2.05	11.9	18.1	24.3	36.9	49.7	62.5	75.4	88.4	101.4
2.10	12.4	18.8	25.3	38.4	51.6	64.9	78.4	91.8	105.4
2.15	12.8	19.5	26.2	39.8	53.5	67.4	81.4	95.4	109.5
2.20	13.3	20.2	27.2	41.3	55.5	69.9	84.4	98.9	113.6
2.25	13.7	20.9	28.1	42.7	57.5	72.4	87.5	102.6	117.8
2.30	14.2	21.6	29.1	44.2	59.6	75.0	90.6	106.2	122.0
2.35	14.7	22.4	30.1	45.7	61.6	77.6	93.8	110.0	126.3
2.40	15.2	23.0	31.1	47.3	63.7	80.3	97.0	113.7	130.7
2.45	15.6	23.8	32.1	48.8	65.8	82.9	100.2	117.6	135.1
2.50	16.1	24.6	33.1	50.4	67.9	85.6	103.5	121.4	139.5

Table 1. Free-flow discharge values for Parshall flumes in cubic feet per second.

Montana flume will not measure if it is even partially submerged. More information about submergence is given in MT 9128.

3. Measure the upstream head (H_a). H_a is measured at a point two-thirds of the distance from the crest to the flume entrance. For most irrigation measurements, a staff gage attached to the flume wall at this point is satisfactory. When precise measurement is required, a stilling well (a pipe set outside the flume but connected to the water in the flume) should be installed so that minor water fluctuations are dampened.

4. Table 2 gives the discharge rate for one- to eight-foot flumes for upstream heads in 0.05 foot increments. The figures can be interpolated when accuracy requires gage readings to 0.01 feet, or extended tables can be obtained. For example, the discharge rate through a two-foot flume with an H_a reading of 1.10 feet is 9.27 cubic feet per second.

Summary

A Montana flume is an excellent measuring device which has stood the tests of time and use. The flume can only be used in a steep ditch or where there is a natural drop so that it will not submerge. When conditions are appropriate it is an excellent choice.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second} \times \text{hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute} \times \text{hours}}{450 \times \text{area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches} \times \text{hours}}{40 \times \text{area irrigated in acres}}$$

File under: Water Measurement
A-5 (Devices and Methods)
Issued February 1992 1742000292 MS

Water Measurement

MT 9128 (AG)

Montana (Short Parshall) Flume (Part 2)

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

A general description of the Montana (short Parshall) flume appears in MT 9127. This bulletin gives flume dimensions and describes sizing, locating and building the flume. This information is quite technical and intended for use by technicians, contractors, and engineers.

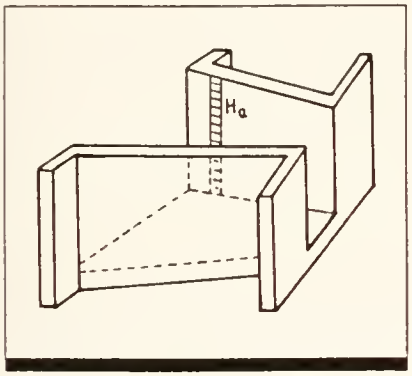

Figure 1. A typical Montana flume.

Flume shape and dimensions

A Montana flume is shown in Figure 1. The flume consists of a converging section and throat also called a crest. The flume size is designated by the crest width and is normally in one-foot increments. Section and plan views are shown in Figure 2. Montana flumes do not protect the channel downstream of the crest from erosion and can not measure partially submerged flows as the Parshall flume can.

Table 2 gives flume dimensions with the letter designation corresponding to those in Figure 2. The height G equals three feet or less depending on the required capacity and flow depth.

Locating and sizing the flume

When installing a flume the following recommendations should be followed.

• Locate the flume in a straight section of ditch so the water will flow smoothly into the converging section.

Water Should Be Measured Because . . .

Water measurement is the foundation of water management and economical crop production. Measuring and applying the proper amount of water saves you money and protects water resources by decreasing soil erosion, fertilizer leaching, and waste water problems.

Montana law requires measuring devices on all streams for which water commissioners have been appointed. A commissioner cannot deliver water unless measuring devices are in place. Eventually all Montana waters will be decreed. You can protect your water right by accurately measuring and recording flow rates and times of use.

Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

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Funded by the Ag Energy Conservation Program, Montana Department of Natural Resources and Conservation. Sponsored by Gallatin County Conservation District

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A-6

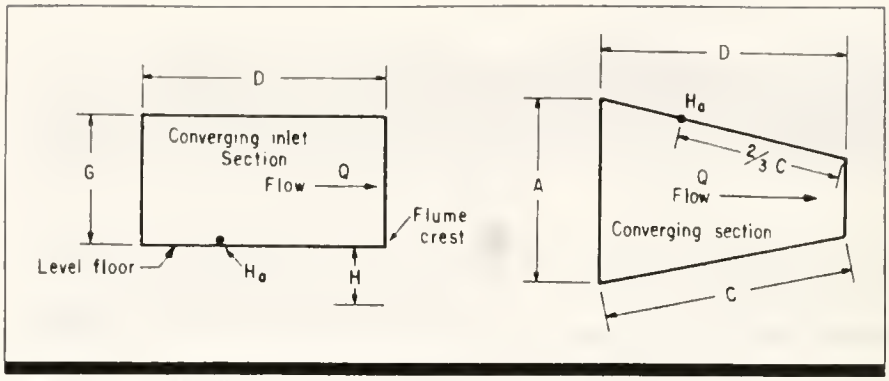

Figure 2. Section and Plan views of a Montana Flume.

• Locate the flume where flow will not be submerged by backwater from downstream.

• Provide for easy accessibility for maintenance and measurement.

The most difficult aspect of flume location is setting the flume at the proper height in relation to the ditch bottom and banks. The flume is an obstruction in the channel and causes a rise in the water elevation upstream. The water must rise from the ditch bottom, pass through the converging section, then drop over the crest. Submerged flows cannot be measured with the Montana flume and must be avoided.

You can avoid submerged flows if you know the downstream water levels at which submergence occurs. A flume is submerged when the depth of water in the throat divided by the flow depth in the converging section exceeds a certain percent. The allowable percent value depends on the size (throat width) of the flume. The flume size in feet with allowable percent shown in parentheses are:

1 (62), 1.5 (64), 2 (66), 3 (68), 4 (70), 5 (72), 6 (74), 7 (76), and 8 (78).

In other words, a particular size flume should be set so that the water does not back up into the throat to a depth greater than the stated percentage multiplied by the upstream head. Submergence can be avoided by setting the flume in a steep section of ditch or at a drop, choosing the proper flume size, and setting the flume at the proper height above the ditch bottom.

For a particular flow rate and channel, it is necessary to determine the flume size and the maximum value of H_a. As a general rule the flume size should be about 40 percent of the channel width. Several flume sizes may be feasible at a given location so check to see which size works best. It is much easier to make these trials on paper than with steel or concrete.

Figure 3 depicts the relationships of flow depths through a flume and shows an example. The analysis of proper flume size and how the flume should be set is hard to

Throat Width	A	B	C	D	Flow rate, cfs Min.	Max.
1 ft	2 ft 9¼ in	2 ft	4 ft 6 in	4 ft 4⅞ in	.11	16.1
1.5ft	3ft 4⅜in	2ft 6in	4ft 9in	4ft 7⅞in	.15	24.6
2ft	3ft 11½in	3ft	5 ft	4ft 10⅞in	.42	33.1
3ft	5ft 1⅞in	4ft	5ft 6in	5ft 4¾in	.61	50.4
4ft	6ft 4¼in	5ft	6ft	5ft 10⅝in	1.3	67.9
5ft	7ft 6⅝in	6ft	6ft 6in	6ft 4½in	1.6	85.6
6ft	8ft 9in	7ft	7ft	6ft 10⅜in	2.6	103.5
7ft	9ft 11⅜in	8ft	7ft 6in	7ft 4¼in	3.0	121.4
8ft	11ft 1¾in	9ft	8ft	7ft 10⅛in	3.5	139.5

Table 2. Parshall flume dimensions for various throat widths and flow capacities.

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

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Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

follow and complicated, but there are no shortcuts. If you don't understand the following, seek help.

The steps in analysis are:

1. Determine the approximate maximum channel discharge in cubic feet per second.

2. Estimate the desired flume size.

3. Determine the flow depth at the maximum discharge rate from inspection of the banks or from canal specifications.

4. From Table 1 in MT 9127, determine the upstream head (H_a) at the maximum discharge rate.

5. Determine the submergence percentage for the desired flume size.

6. Multiply the upstream head (H_a) by the submergence percentage to determine the distance the flume crest should be set below the original maximum flow depth.

7. Subtract the distance calculated in step 6 from the original flow depth to determine the height of the flume floor above the channel bottom.

8. Subtract the distance calculated in step 6 from the upstream head (H_a). Add the result to the original flow depth to calculate the rise in upstream water level after the flume is installed. Verify that the banks upstream can handle this increased depth.

This analysis is reiterated in the following example. Again refer to Figure 3.

Steps 1, 2, 3. Suppose you are considering a two-foot flume, a maximum discharge of 27.0 cubic feet per second, and an original flow depth of 2.5 feet.

Step 4. Using Table 1 in MT 9127 and interpolating, for a two-foot flume with a discharge of 27.0 cubic feet per second, H_a equals 2.19 feet.

Step 5. To prevent submergence for a two-foot flume, the allowable submergence ratio is 66 percent.

Step 6. Thus the flume crest (flume floor) should be set below the original maximum flow depth an amount equal to 2.19 x 0.66 or 1.45 feet.

Step 7. Subtract 1.45 feet from the original flow depth of 2.5 feet to determine that the crest floor should be 1.05 feet above the channel bottom.

Step 8. The increase in flow depth upstream of the flume is 2.19 feet minus 1.45 feet or 0.74 feet. The water flowing at a 2.5 foot depth upstream of the flume prior to installation will rise 0.74 feet to flow at a depth of 3.24 feet after installation. The banks upstream must be able to handle this greater water depth.

Several sizes of flumes can carry the 27.0 cubic feet per second flow rate used in this example. These sizes should be evaluated before construction to see which size would best fit the ditch and situation. The narrowest flume may not always be the most economical because of the wing wall length needed to span the channel and the increased upstream water depth.

Building a flume

Dimensions for the Montana flume are shown in Figure 2 and Table 2. The flume shape is simple but these dimen-

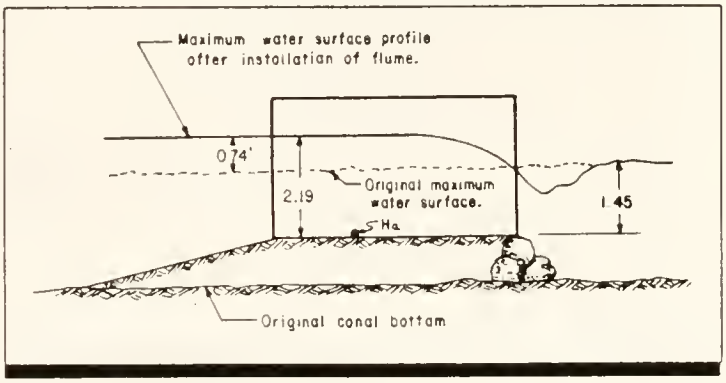

Figure 3. Analysis of upstream and downstream water elevations and crest elevation above the channel bottom.

sions must be followed exactly for the water measurement to be accurate. Prefabricated sheet metal flumes have the advantage of in-shop construction where pieces can be properly jigged and bent or welded. This is difficult in a farm shop when generally only one flume is built. Prefabricated flumes are the best choice for small sizes. Many fabricators only make the Parshall flume. You may be able to have the Montana flume built by special order. Flumes built in place are generally cheaper for larger sizes.

Flumes of treated lumber or concrete can be built in place. The floor should be level and the sides should be plumb. Adequate steel reinforcement should be used. The form work for the Montana flume is relatively simple and can be done by anyone with reasonable carpentry skills. The work cannot be sloppy, however, and a any contractor engaged should be required to guarantee exact dimensions and good workmanship.

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File under: Water Measurement
A-6 (Devices and Methods)
Issued February 1992 1752000292 MS

Water Measurement

MT 9132 (AG)

The Replogle Flume (Broad-crested Weir)

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

What is a Replogle flume?

The Replogle flume is named for a U.S. Department of Agriculture researcher who helped develop it. A picture of the flume is shown in Figure 1. The flume usually consists of a section of concrete-lined ditch with a sill and ramp rising from the bottom. The ramp accelerates the water as it passes over the sill. In a typical ditch the sill is about two feet long and is above the bottom about two thirds of the normal water depth. The ramp is built on a slope of about 3:1 on the upstream side of the sill. There is no ramp on the downstream side. The flume is normally made of concrete although wood flumes have been used in a few applications. The flume has been most widely used in concrete-lined ditches. It can be used in earth ditches if a short section of concrete lining is provided.

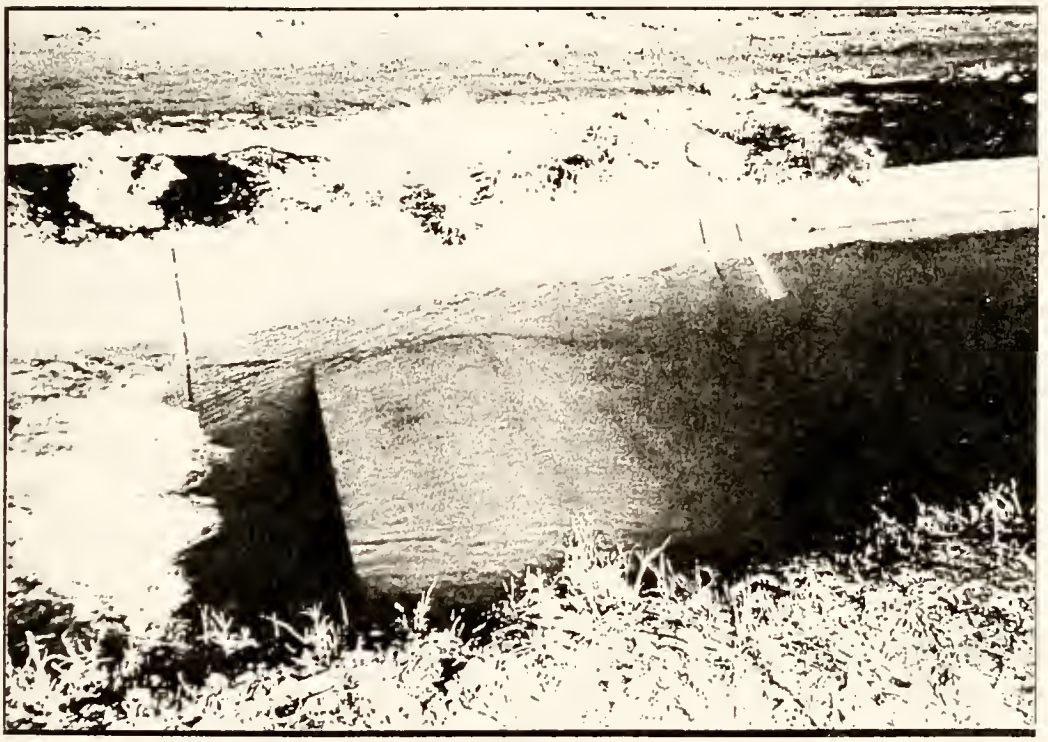

Figure 1. A Replogle flume.

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Water Should Be Measured Because . . .

Water measurement is the foundation of water management and economical crop production. Measuring and applying the proper amount of water saves you money and protects water resources by decreasing soil erosion, fertilizer leaching, and waste water problems.

Montana law requires measuring devices on all streams for which water commissioners have been appointed. A commissioner cannot deliver water unless measuring devices are in place. Eventually all Montana waters will be decreed. You can protect your water right by accurately measuring and recording flow rates and times of use.

Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

The Replogle flume is virtually the only open channel water measuring device which has evolved during the computer age. Because of the computer and mathematical expertise available, the development of the Replogle flume followed a different approach than was used for previous devices such as the Parshall flume. The Replogle flume can be built to fit a canal or ditch and mathematical modeling can then be used to generate a flow-rating table for that specific facility. The Replogle flume can thus be constructed with varying dimensions and still give accurate measurement. Standard tables have been developed for some small concrete lined ditches.

Advantages

• The flume can operate in relatively flat ditches with little head loss.

• The flume is insensitive to the velocity of the inflowing water and can be used in ditches without a stilling pond.

• The flume is extremely easy to construct. Meticulous attention to detail is not required.

• The flume is rugged. It consists of a mass of concrete in the ditch bottom and does not have vertical walls which are easily overturned.

• The flume can be built to fit almost any shape canal or ditch, and a flow-rating table can be developed for that particular flume.

• Accuracy is about plus or minus two percent if reasonable attention is paid to construction detail.

• The cost is probably the lowest of any measuring device.

Disadvantages•

• Professional help must be obtained to size the flume and develop the rating curve.

• The flume has not been widely used. If the measurement is ever challenged, an expert witness may be necessary to testify about dimensions and the rating curve. The flume has been carefully developed by USDA engineers and the basic workings of the flume should stand any test.

• Silt may build up downstream of the sill. Any silt deposition will have to be periodically cleaned or the measurement will be inaccurate.

• A river or canal system that has many Replogle flumes may have many flow-rating curves. With a Parshall flume, for example, every flow-rating curve is the same. This might lead to questioning of measurements made by users or a water master.

• The flume can not be used to control the flow of water. A separate headgate is required.

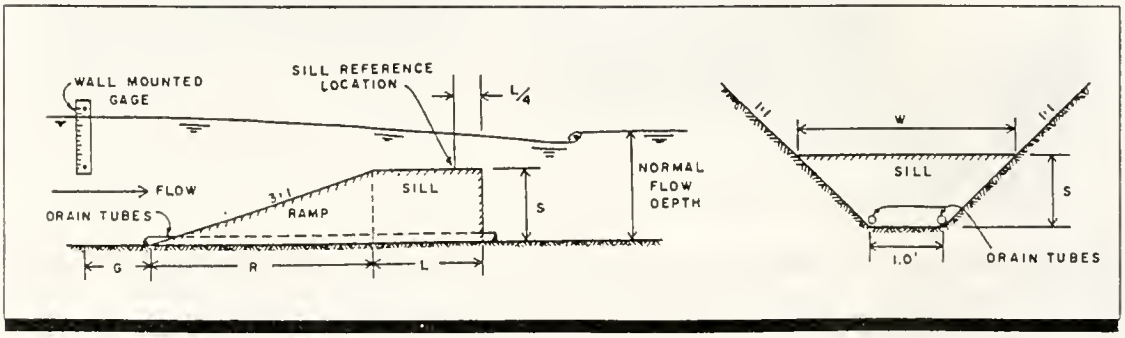

Figure 2. The general shape of the Replogle flume.

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft^3), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

Location and construction

The first step in selecting a flume is to determine the size, shape, and slope of the channel. The expected minimum and maximum discharge also should be determined. The channel section should be straight and uniform. With earth channels it may be necessary to concrete line a section approximately 20 feet long. The sill will be located at the center of this section. The approximate flume shape is shown in Figure 2. Worksheets and/or an existing computer program can be used to evaluate the alternatives of sill height, width, and length. By varying these dimensions, the appropriate criteria involving upstream and downstream freeboard and submergence can be determined. Specific criteria and exact dimensions will be determined during this design process. The process is not difficult but does require specialized knowledge and help should be secured from the Soil Conservation Service or a qualified consultant. When dimensions are determined the water user with only fundamental carpentry and concrete skills can easily build a serviceable flume.

The first step in construction is to cut two identical pieces of plywood to make a form that matches the sill cross section. These pieces will normally be trapezoidal in shape and may have to be reinforced. Notch the bottom corners or center for insertion of one or more drain tubes. Cut spacers the length of the sill to hold the two sides of the form apart. With the spacers between the two sides of the form, use wire ties between the sides to hold them firmly against the spacers. This process makes a sturdy box for pouring the sill. Insert the drain tubes (typically 2-inch PVC pipe) and shim the form so that the top is level. The drain pipes extend through the sill and the ramp.

Remove the spacers as the form is filled with concrete. Use a screed board and the form boards as guides for screeding and troweling the sill to a smooth level surface. Any surplus concrete can be placed on the upstream side on the ditch floor as the bottom of the ramp section. When the sill has taken an initial set, remove the upstream side of the form and pour the ramp. The ramp is on a 3:1 slope. Chalk marks on the ditch sides help show the proper slope. The ramp needs to be reasonably smooth but its finish is not critical.

The reference point for the gage is shown in Figure 2. Using this sill point as a reference helps eliminate error resulting from a non-level sill. The gage itself should be located one foot upstream from the beginning of the ramp. The bottom of the gage (zero) should be set level with the sill reference point. Generally it is most convenient to fasten the gage to the side of the ditch, which will require translation of the vertical gage depths to slope distances. The gage can be mounted on the concrete with lead anchors and screws. Care should be taken in setting the gage as a mis-set gage is a common source of error.

Water measurement

When a Replogle flume is properly designed and constructed, the actual water measurement is extremely simple. The rating table generated with the computer after construction matches actual dimensions and conditions. Thus if some error was made during construction in sill width, for example, the computer can compensate for that error. Using the rating table, the water user simply reads the gage and looks up the flow rate. Even this step can be eliminated by marking the gage in flow units and reading the flowrate directly.

Summary

The Replogle flume is extremely easy to use and build. It is a rugged and simple measuring device which is accurate and inexpensive. Expert help is required during design and in the generation of a rating curve.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second} \times \text{hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute} \times \text{hours}}{450 \times \text{area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches} \times \text{hours}}{40 \times \text{area irrigated in acres}}$$

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Selection and Installation of Cutthroat Flumes for Measuring Irrigation and Drainage Water

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Introduction

Procedures and methods for more accurate measurement and improved management of water are continually being sought to make better use of our water resources. Of all the devices and structures developed for measuring water, measuring flumes are among the most widely accepted and used. The most common measuring flume is the Parshall flume developed by Ralph Parshall (1926) at Colorado State University.

The problem of determining the flow rate in open channels is one which has been considered for many years. The rapidly increasing value of water is commanding new interest in the development of new open channel flow measuring devices. Water measuring devices are important for: (a) water conservation; (b) equitable distribution of water; (c) determining the amount of available water; (d) meeting legal requirements; and (e) successful management of the available supply.

A water measuring flume consists of an open channel structure containing a constricted section. The constriction is formed by either raising the floor or by reducing the width between the sidewalls, or both. The discharge characteristics are the same for both types; however, the raised floor is usually classified as a weir rather than a flume. Also, unless great care is taken in designing the raised floor section, some of the self cleaning properties may be lost.

A flow measuring device which has been recently developed is the Cutthroat flume (Skogerboe, Hyatt, Anderson, and Eggleston, 1967). The original studies have been extended by Bennett (1972) in rating a group of Cutthroat flumes which have the same geometric shape. Then, since all of the flumes are basically similar, the flow behavior, or discharge characteristics, of other Cutthroat flume sizes can be predicted. Because of this similarity, the behavior of all flumes intermediate in size to those tested is capable of being predicted within a degree of accuracy suitable for field use.

In flat gradient channels, it may be desirable to install a flume to operate under conditions of submerged flow rather than free flow in order to: (1) reduce energy losses, and (2) place the flume on the channel bed to minimize the increase in water surface elevation upstream from the flume. The purpose of the research efforts reported herein was to develop a flume which would operate satisfactorily under both free flow and submerged flow conditions.

Development of Flume

Previous studies by Robinson and Chamberlain (1960) and Hyatt (1965) indicate that a flume having a flat bottom is satisfactory for both free flow and submerged flow operation. The advantages of a level flume floor, as opposed to the inclined floor in the throat and exit sections of the Parshall flume are: (a) ease of construction; (b) the flume can be placed inside a concrete-lined channel; and (c) the flume can be placed on the channel bed.

Ackers and Harrison (1963) recommend a maximum convergence of 3:1 for a flume inlet section. Experimental work indicated that this recommendation had merit, and consequently a 3:1 convergence (Fig. 1) was used in developing a flat-bottomed flume.

Earlier studies regarding the length of the throat section in flow measuring flumes, discussed in a preceding report (Skogerboe, Hyatt and Eggleston, 1967), showed that flow depths measured in the exit section of a flume resulted in more accurate submerged flow calibration curves than calibrations employing flow depth measurements in the throat section. The water surface profile changes rapidly in the throat section as compared with the exit section where the water surface profile is more nearly horizontal. Consequently, a flow depth in the exit section of the flat-bottomed flume was selected for measurement.

The earlier study by Hyatt (1965) indicated that when the divergence of the flume exit section exceeded 6:1 (for every 6 parts of length, the width increases by 1 part), separation would occur, and a major portion of the flow would adhere to one of the sidewalls. Although numerous divergences and lengths of exit section were tested, the 6:1 divergence proved most satisfactory as a balance between flow separation and fabrication costs.

Since the downstream flow depth was to be measured in the exit section, there appeared to be no apparent advantage in having a throat section. Consequently, testing was initiated with a flat-bottomed flume having only an entrance and an exit section. The flume performed very well. One distinct hydraulic advantage of removing the throat section was improved flow conditions in the exit section. The converging inlet section tended to confine the flow into a jet which traveled along the flume centerline, thus assisting in the prevention of flow separation.

The rectangular flat-bottomed flume, which resulted from the testing program, is illustrated in Fig. 1. Since the flume has no throat section (zero throat length), the flume was given the name "Cutthroat" by the developers (Skogerboe, Hyatt, Anderson, and Eggleston, 1967).

The most obvious advantage of a Cutthroat flume is economy, since fabrication is facilitated by a flat-bottom and removal of the throat section (zero throat length). Another advantage is that every flume length has the same entrance and exit section lengths, which allows the same forms or patterns to be used for any desired throat width.

The Cutthroat flume can operate either as a free or submerged flow structure as indicated in this report. Methods for obtaining submerged flow calibration curves and free flow tables are developed and their use illustrated. Discussion and examples regarding the practical aspects of installing, operating and maintaining the structures are given.

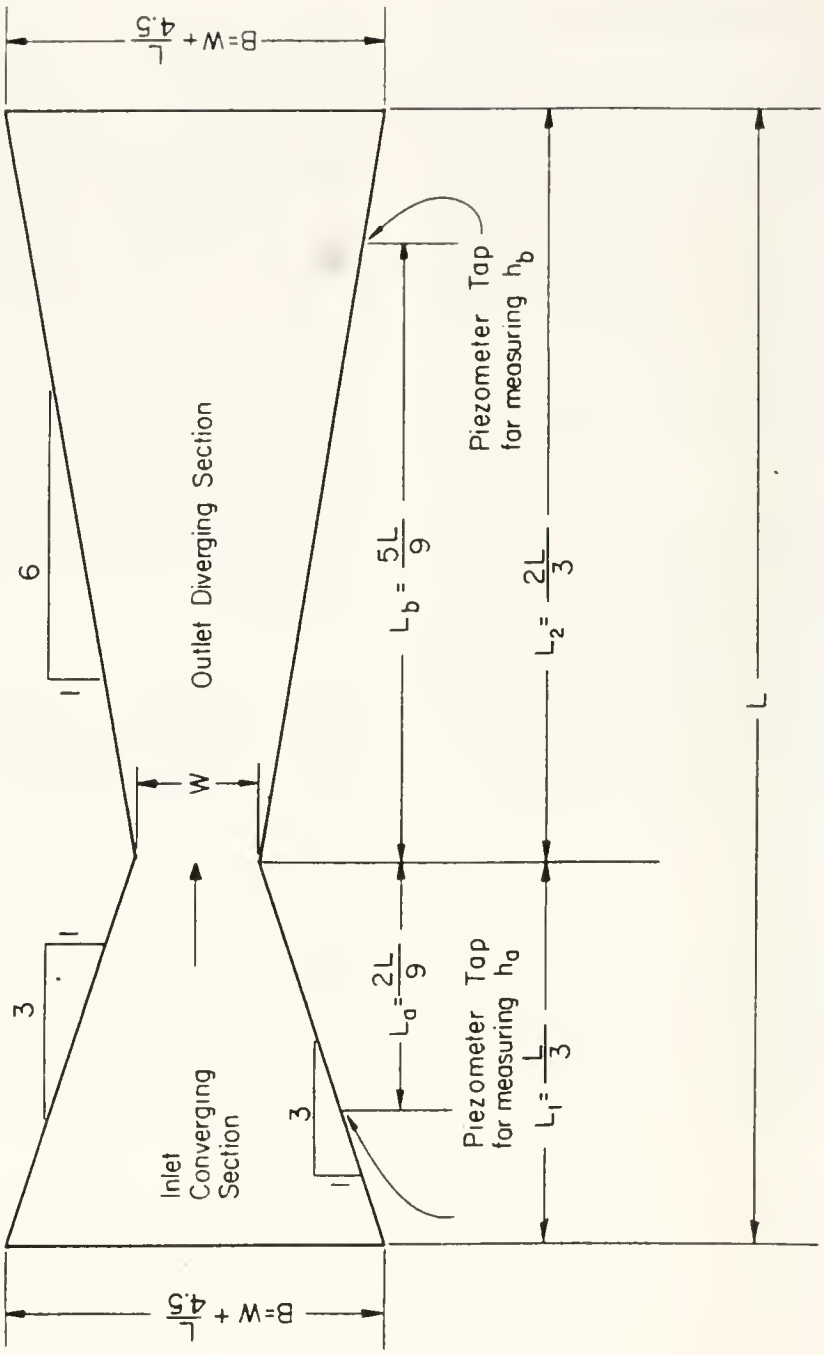


Figure 1. Definition sketch of a Cutthroat flume.

Table 3. Free flow calibrations for selected Cutthroat flumes.

(Values listed are discharge in cfs)

h_a, ft	4INX3FT	8INX3FT	12INX3FT	16INX3FT	8INX6FT	16INX6FT	24INX6FT	32INX6FT	12INX9FT	24INX9FT	36INX9FT	48INX9FT
.02	.00	.00	.00	.00	.00	.01	.01	.02	.01	.02	.02	.03
.04	.00	.01	.01	.02	.01	.03	.04	.05	.02	.05	.07	.10
.06	.01	.02	.03	.03	.02	.05	.07	.10	.04	.09	.13	.18
.08	.01	.03	.04	.06	.04	.08	.12	.16	.07	.14	.21	.28
.10	.02	.04	.07	.09	.06	.11	.17	.23	.10	.20	.30	.40
.12	.03	.06	.09	.12	.08	.15	.23	.31	.13	.26	.39	.53
.14	.04	.08	.12	.16	.10	.20	.30	.40	.16	.33	.50	.67
.16	.05	.10	.15	.21	.12	.25	.37	.50	.20	.41	.62	.83
.18	.06	.13	.19	.26	.15	.30	.45	.61	.24	.49	.74	1.00
.20	.09	.15	.23	.31	.17	.35	.54	.72	.28	.58	.88	1.18
.22	.09	.18	.28	.37	.20	.42	.63	.85	.33	.67	1.02	1.37
.24	.11	.21	.33	.44	.24	.48	.73	.98	.38	.77	1.16	1.56
.26	.12	.25	.38	.51	.27	.55	.83	1.11	.43	.87	1.32	1.77
.28	.14	.29	.43	.58	.30	.62	.94	1.26	.48	.98	1.48	1.99
.30	.16	.32	.49	.66	.34	.69	1.05	1.41	.54	1.09	1.65	2.22
.32	.18	.36	.55	.74	.38	.77	1.17	1.57	.59	1.21	1.82	2.45
.34	.20	.41	.62	.83	.42	.85	1.29	1.73	.65	1.32	2.00	2.69
.36	.22	.45	.69	.92	.46	.93	1.42	1.90	.71	1.45	2.19	2.94
.38	.25	.50	.76	1.02	.50	1.02	1.55	2.08	.77	1.58	2.38	3.20
.40	.27	.55	.83	1.12	.55	1.11	1.69	2.26	.84	1.71	2.58	3.47
.42	.30	.60	.91	1.22	.59	1.20	1.83	2.45	.90	1.84	2.79	3.74
.44	.32	.66	.99	1.33	.64	1.30	1.97	2.65	.97	1.98	3.00	4.03
.46	.35	.71	1.08	1.44	.69	1.40	2.12	2.85	1.04	2.12	3.21	4.31
.48	.38	.77	1.17	1.56	.74	1.50	2.28	3.05	1.11	2.27	3.43	4.61
.50	.41	.83	1.26	1.68	.79	1.60	2.44	3.26	1.19	2.42	3.66	4.91
.52	.44	.89	1.35	1.81	.84	1.71	2.60	3.48	1.26	2.57	3.89	5.22
.54	.47	.96	1.45	1.94	.90	1.82	2.76	3.71	1.34	2.73	4.12	5.54
.56	.50	1.02	1.55	2.07	.95	1.93	2.94	3.93	1.42	2.89	4.36	5.86
.58	.54	1.09	1.65	2.21	1.01	2.05	3.11	4.17	1.50	3.05	4.61	6.19
.60	.57	1.16	1.76	2.36	1.07	2.16	3.29	4.41	1.58	3.21	4.86	6.53
.62	.61	1.23	1.87	2.50	1.12	2.28	3.47	4.65	1.66	3.38	5.11	6.87
.64	.64	1.31	1.98	2.65	1.18	2.40	3.66	4.90	1.74	3.55	5.37	7.22
.66	.68	1.38	2.09	2.81	1.25	2.53	3.85	5.15	1.83	3.73	5.64	7.58
.68	.72	1.46	2.21	2.97	1.31	2.66	4.04	5.41	1.92	3.91	5.91	7.94
.70	.76	1.54	2.33	3.13	1.37	2.79	4.24	5.68	2.01	4.09	6.18	8.31
.72	.80	1.62	2.46	3.29	1.44	2.92	4.44	5.95	2.10	4.27	6.46	8.68
.74	.84	1.71	2.59	3.47	1.50	3.05	4.64	6.22	2.19	4.46	6.74	9.06
.76	.88	1.79	2.72	3.64	1.57	3.19	4.85	6.50	2.28	4.65	7.03	9.44
.78	.92	1.88	2.85	3.82	1.64	3.33	5.06	6.78	2.38	4.84	7.32	9.83
.80	.97	1.97	2.98	4.00	1.71	3.47	5.28	7.07	2.47	5.03	7.61	10.23
.82	1.01	2.06	3.12	4.19	1.78	3.62	5.50	7.37	2.57	5.23	7.91	10.63
.84	1.06	2.15	3.27	4.38	1.85	3.76	5.72	7.66	2.67	5.43	8.21	11.04
.86	1.10	2.25	3.41	4.57	1.93	3.91	5.94	7.97	2.77	5.64	8.52	11.45
.88	1.15	2.35	3.56	4.77	2.00	4.06	6.17	8.27	2.87	5.84	8.83	11.87
.90	1.20	2.45	3.71	4.97	2.08	4.21	6.41	8.59	2.97	6.05	9.15	12.29
.92	1.25	2.55	3.86	5.17	2.15	4.37	6.64	8.90	3.07	6.26	9.47	12.72
.94	1.30	2.65	4.02	5.38	2.23	4.53	6.88	9.22	3.18	6.47	9.79	13.16
.96	1.35	2.76	4.17	5.59	2.31	4.69	7.12	9.55	3.28	6.69	10.11	13.60
.98	1.40	2.86	4.34	5.81	2.39	4.85	7.37	9.88	3.39	6.91	10.45	14.04
1.00	1.46	2.97	4.50	6.03	2.47	5.01	7.62	10.21	3.50	7.13	10.78	14.49

Table 3 (continued)

h_o, ft	4INX3FT	8INX3FT	12INX3FT	16INX3FT	8INX6FT	16INX6FT	24INX6FT	32INX6FT	12INX9FT	24INX9FT	36INX9FT	48INX9FT
1.02	1.51	3.08	4.67	6.25	2.55	5.18	7.87	10.55	3.61	7.35	11.12	14.94
1.04	1.57	3.19	4.84	6.48	2.63	5.34	8.13	10.89	3.72	7.58	11.46	15.40
1.06	1.62	3.31	5.01	6.71	2.72	5.52	8.38	11.24	3.83	7.81	11.81	15.87
1.08	1.68	3.42	5.18	6.95	2.80	5.69	8.65	11.59	3.95	8.04	12.16	16.34
1.10	1.74	3.54	5.36	7.19	2.89	5.86	8.91	11.94	4.05	8.27	12.51	16.81
1.12	1.80	3.65	5.54	7.43	2.97	6.04	9.18	12.30	4.18	8.51	12.86	17.29
1.14	1.86	3.78	5.73	7.67	3.06	6.22	9.45	12.67	4.29	8.75	13.22	17.78
1.16	1.92	3.90	5.91	7.92	3.15	6.40	9.72	13.03	4.41	8.99	13.59	18.27
1.18	1.98	4.03	6.10	8.18	3.24	6.58	10.00	13.41	4.53	9.23	13.96	18.76
1.20	2.04	4.15	6.29	8.43	3.33	6.76	10.28	13.78	4.65	9.48	14.33	19.26
1.22	2.10	4.28	6.49	8.69	3.42	6.95	10.57	14.16	4.77	9.72	14.70	19.76
1.24	2.17	4.41	6.69	8.96	3.52	7.14	10.85	14.54	4.90	9.97	15.08	20.27
1.26	2.23	4.54	6.88	9.23	3.61	7.33	11.14	14.93	5.02	10.23	15.46	20.78
1.28	2.30	4.68	7.09	9.50	3.70	7.52	11.43	15.32	5.14	10.48	15.84	21.30
1.30	2.36	4.81	7.29	9.77	3.80	7.72	11.73	15.72	5.27	10.74	16.23	21.82
1.32	2.43	4.95	7.50	10.05	3.90	7.91	12.03	16.12	5.40	10.99	16.62	22.34
1.34	2.50	5.09	7.71	10.33	3.99	8.11	12.33	16.52	5.53	11.26	17.02	22.87
1.36	2.57	5.23	7.92	10.62	4.09	8.31	12.63	16.93	5.65	11.52	17.42	23.41
1.38	2.64	5.37	8.14	10.91	4.19	8.51	12.94	17.34	5.78	11.78	17.82	23.95
1.40	2.71	5.52	8.36	11.20	4.29	8.72	13.25	17.76	5.92	12.05	18.22	24.49
1.42	2.78	5.66	8.58	11.50	4.39	8.92	13.56	18.18	6.05	12.32	18.63	25.04
1.44	2.85	5.81	8.80	11.80	4.50	9.13	13.88	18.60	6.18	12.59	19.04	25.59
1.46	2.93	5.96	9.03	12.10	4.60	9.34	14.20	19.03	6.32	12.87	19.45	26.15
1.48	3.00	6.11	9.26	12.41	4.70	9.55	14.52	19.46	6.45	13.14	19.87	26.71
1.50	3.07	6.26	9.49	12.72	4.81	9.76	14.84	19.89	6.59	13.42	20.29	27.28
1.52	3.15	6.42	9.72	13.03	4.91	9.98	15.17	20.33	6.73	13.70	20.72	27.84
1.54	3.23	6.57	9.96	13.35	5.02	10.20	15.50	20.77	6.86	13.98	21.14	28.42
1.56	3.30	6.73	10.20	13.67	5.13	10.41	15.83	21.22	7.00	14.27	21.57	29.00
1.58	3.38	6.89	10.44	13.99	5.24	10.63	16.17	21.67	7.14	14.55	22.01	29.58
1.60	3.46	7.05	10.69	14.32	5.35	10.86	16.51	22.12	7.29	14.84	22.44	30.16
1.62	3.54	7.22	10.93	14.65	5.46	11.08	16.85	22.58	7.43	15.13	22.88	30.75
1.64	3.62	7.38	11.18	14.98	5.57	11.31	17.19	23.04	7.57	15.43	23.32	31.35
1.66	3.70	7.55	11.43	15.32	5.68	11.53	17.54	23.50	7.72	15.72	23.77	31.95
1.68	3.79	7.71	11.69	15.66	5.79	11.76	17.88	23.97	7.86	16.02	24.22	32.55
1.70	3.87	7.88	11.95	16.01	5.91	12.00	18.24	24.44	8.01	16.32	24.67	33.16
1.72	3.95	8.05	12.21	16.36	6.02	12.23	18.59	24.92	8.16	16.62	25.12	33.77
1.74	4.04	8.23	12.47	16.71	6.14	12.46	18.95	25.39	8.30	16.92	25.58	34.38
1.76	4.13	8.40	12.73	17.06	6.25	12.70	19.31	25.88	8.45	17.22	26.04	35.00
1.78	4.21	8.58	13.00	17.42	6.37	12.94	19.67	26.36	8.60	17.53	26.50	35.62
1.80	4.30	8.75	13.27	17.78	6.49	13.18	20.03	26.85	8.76	17.84	26.97	36.25
1.82	4.39	8.94	13.54	18.15	6.61	13.42	20.40	27.34	8.91	18.15	27.44	36.88
1.84	4.48	9.12	13.82	18.52	6.73	13.66	20.77	27.84	9.05	18.46	27.91	37.51
1.86	4.57	9.30	14.10	18.89	6.85	13.91	21.14	28.34	9.22	18.77	28.38	38.15
1.88	4.65	9.49	14.38	19.26	6.97	14.16	21.52	28.84	9.37	19.09	28.86	38.79
1.90	4.75	9.68	14.66	19.64	7.09	14.40	21.90	29.35	9.53	19.41	29.34	39.44
1.92	4.84	9.86	14.94	20.03	7.22	14.65	22.28	29.86	9.68	19.73	29.82	40.09
1.94	4.94	10.05	15.23	20.41	7.34	14.91	22.66	30.37	9.84	20.05	30.31	40.74
1.96	5.03	10.24	15.52	20.80	7.47	15.16	23.05	30.89	10.00	20.37	30.80	41.40
1.98	5.12	10.44	15.82	21.19	7.59	15.41	23.43	31.41	10.16	20.70	31.29	42.06
2.00	5.22	10.63	16.11	21.59	7.72	15.67	23.83	31.93	10.32	21.02	31.79	42.72

Table 3 (continued)

h_a, ft	4INX3FT	8INX3FT	12INX3FT	16INX3FT	8INX6FT	16INX6FT	24INX6FT	32INX6FT	12INX9FT	24INX9FT	36INX9FT	48INX9FT
2.02	***	***	***	***	7.85	15.93	24.22	32.46	10.48	21.35	32.28	43.39
2.04	***	***	***	***	7.97	16.19	24.61	32.99	10.64	21.68	32.78	44.06
2.06	***	***	***	***	8.10	16.45	25.01	33.52	10.81	22.02	33.29	44.74
2.08	***	***	***	***	8.23	16.72	25.41	34.06	10.97	22.35	33.79	45.42
2.10	***	***	***	***	8.36	16.98	25.82	34.60	11.14	22.69	34.30	46.10
2.12	***	***	***	***	8.50	17.25	26.22	35.14	11.30	23.02	34.81	46.79
2.14	***	***	***	***	8.63	17.52	26.63	35.69	11.47	23.36	35.32	47.48
2.16	***	***	***	***	8.76	17.79	27.04	36.24	11.64	23.70	35.84	48.17
2.18	***	***	***	***	8.89	18.06	27.45	36.79	11.80	24.05	36.36	48.87
2.20	***	***	***	***	9.03	18.33	27.87	37.35	11.97	24.39	36.88	49.57
2.22	***	***	***	***	9.16	18.61	28.29	37.91	12.14	24.74	37.40	50.28
2.24	***	***	***	***	9.30	18.88	28.71	38.48	12.32	25.09	37.93	50.99
2.26	***	***	***	***	9.44	19.16	29.13	39.04	12.49	25.44	38.46	51.70
2.28	***	***	***	***	9.58	19.44	29.56	39.61	12.65	25.79	38.99	52.41
2.30	***	***	***	***	9.71	19.72	29.98	40.19	12.83	26.14	39.53	53.13
2.32	***	***	***	***	9.85	20.01	30.41	40.76	13.01	26.50	40.07	53.86
2.34	***	***	***	***	9.99	20.29	30.85	41.34	13.18	26.86	40.61	54.58
2.36	***	***	***	***	10.13	20.58	31.28	41.92	13.36	27.22	41.15	55.31
2.38	***	***	***	***	10.28	20.86	31.72	42.51	13.54	27.58	41.69	56.04
2.40	***	***	***	***	10.42	21.15	32.16	43.10	13.72	27.94	42.24	56.78
2.42	***	***	***	***	10.56	21.44	32.60	43.69	13.89	28.30	42.79	57.52
2.44	***	***	***	***	10.71	21.74	33.04	44.29	14.07	28.67	43.35	58.26
2.46	***	***	***	***	10.85	22.03	33.49	44.89	14.25	29.04	43.90	59.01
2.48	***	***	***	***	11.00	22.33	33.94	45.49	14.43	29.41	44.46	59.76
2.50	***	***	***	***	11.14	22.62	34.39	46.09	14.62	29.78	45.02	60.51
2.52	***	***	***	***	***	***	***	***	14.80	30.15	45.58	61.27
2.54	***	***	***	***	***	***	***	***	14.98	30.52	46.15	62.03
2.56	***	***	***	***	***	***	***	***	15.17	30.90	46.72	62.79
2.58	***	***	***	***	***	***	***	***	15.35	31.28	47.29	63.56
2.60	***	***	***	***	***	***	***	***	15.54	31.66	47.86	64.33
2.62	***	***	***	***	***	***	***	***	15.73	32.04	48.44	65.11
2.64	***	***	***	***	***	***	***	***	15.91	32.42	49.01	65.88
2.66	***	***	***	***	***	***	***	***	16.10	32.80	49.59	66.66
2.68	***	***	***	***	***	***	***	***	16.29	33.19	50.18	67.45
2.70	***	***	***	***	***	***	***	***	16.48	33.58	50.76	68.23
2.72	***	***	***	***	***	***	***	***	16.67	33.96	51.35	69.02
2.74	***	***	***	***	***	***	***	***	16.86	34.35	51.94	69.82
2.76	***	***	***	***	***	***	***	***	17.06	34.75	52.53	70.61
2.78	***	***	***	***	***	***	***	***	17.25	35.14	53.13	71.41
2.80	***	***	***	***	***	***	***	***	17.44	35.53	53.73	72.22
2.82	***	***	***	***	***	***	***	***	17.64	35.93	54.33	73.02
2.84	***	***	***	***	***	***	***	***	17.83	36.33	54.93	73.83
2.86	***	***	***	***	***	***	***	***	18.03	36.73	55.53	74.64
2.88	***	***	***	***	***	***	***	***	18.23	37.13	56.14	75.46
2.90	***	***	***	***	***	***	***	***	18.43	37.53	56.75	76.28
2.92	***	***	***	***	***	***	***	***	18.62	37.94	57.36	77.10
2.94	***	***	***	***	***	***	***	***	18.82	38.35	57.97	77.93
2.96	***	***	***	***	***	***	***	***	19.02	38.75	58.59	78.76
2.98	***	***	***	***	***	***	***	***	19.22	39.16	59.21	79.59
3.00	***	***	***	***	***	***	***	***	19.43	39.57	59.83	80.42

Fig. 6. Relationship between r_s and r_f.

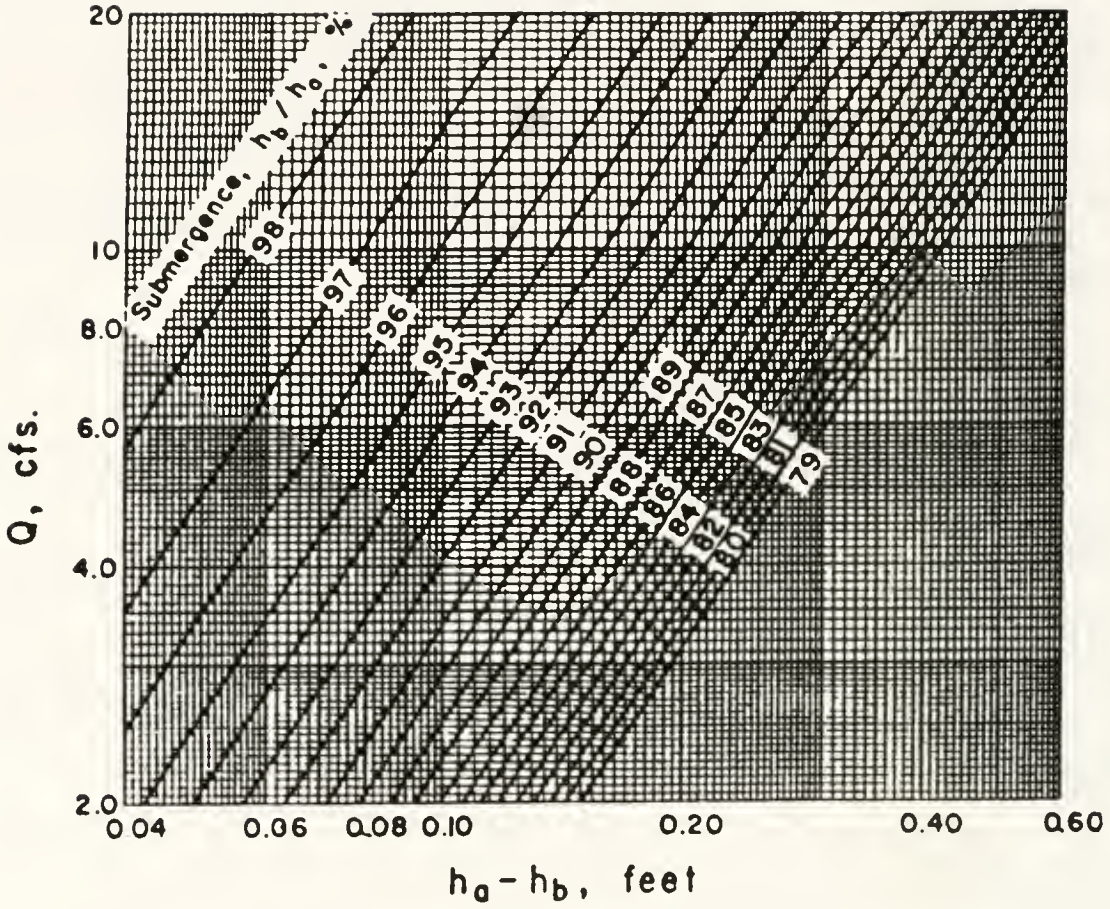


Fig. 7. Submerged flow calibration curves for 1-foot rectangular cutthroat flume.

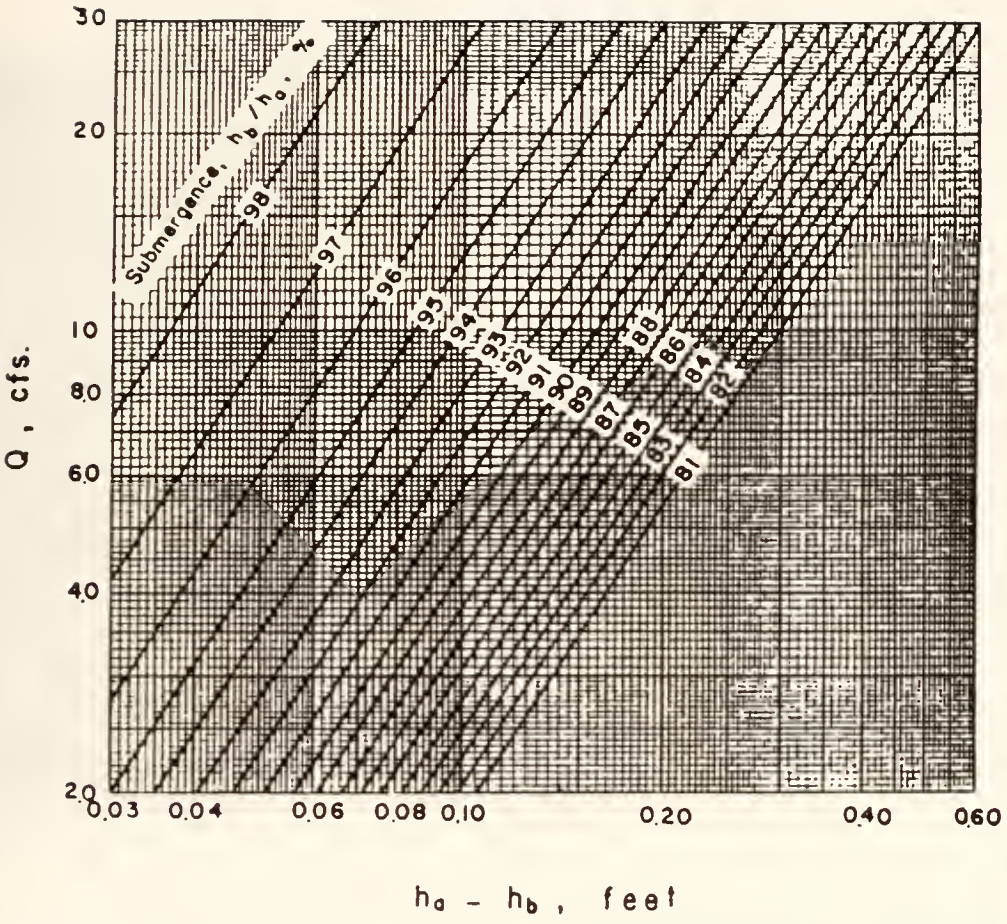


Fig. 8. Submerged flow calibration curves for 1.5-foot rectangular cutthroat flume.

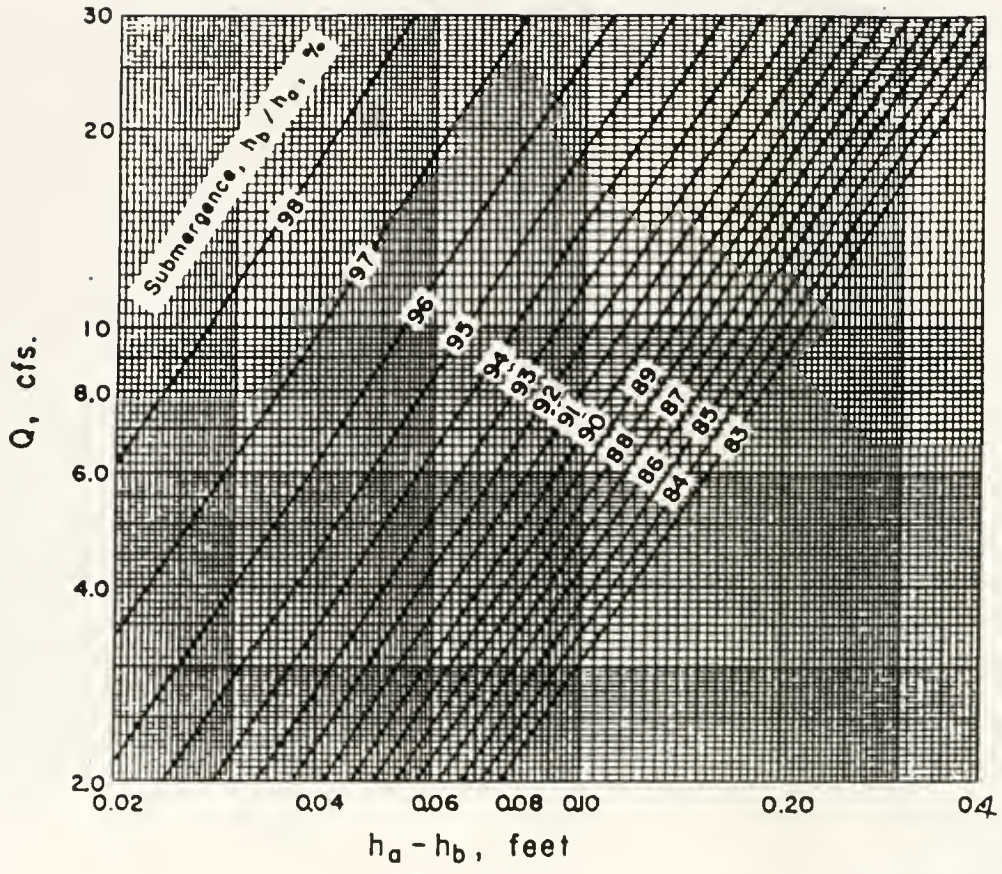


Fig. 9. Submerged flow calibration curves for 2-foot rectangular cutthroat flume.

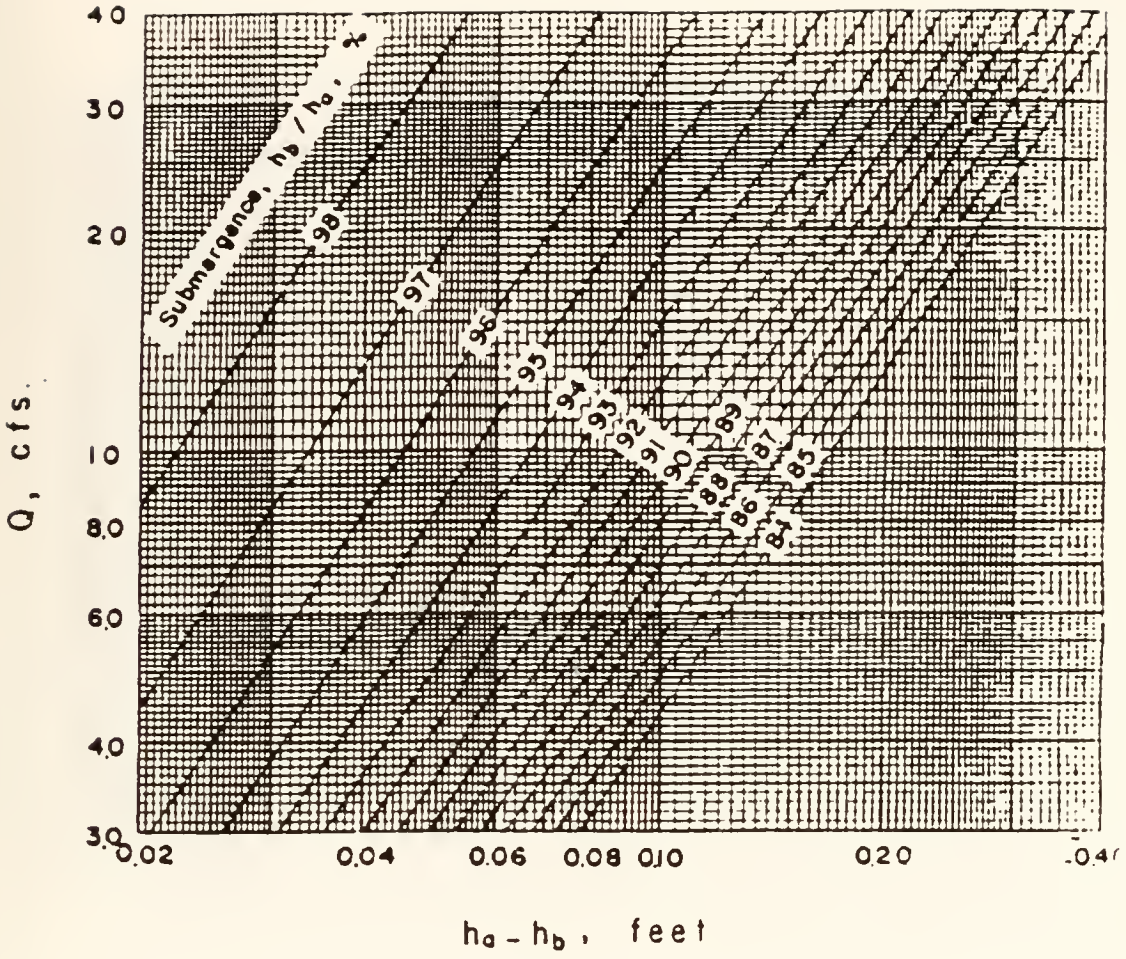
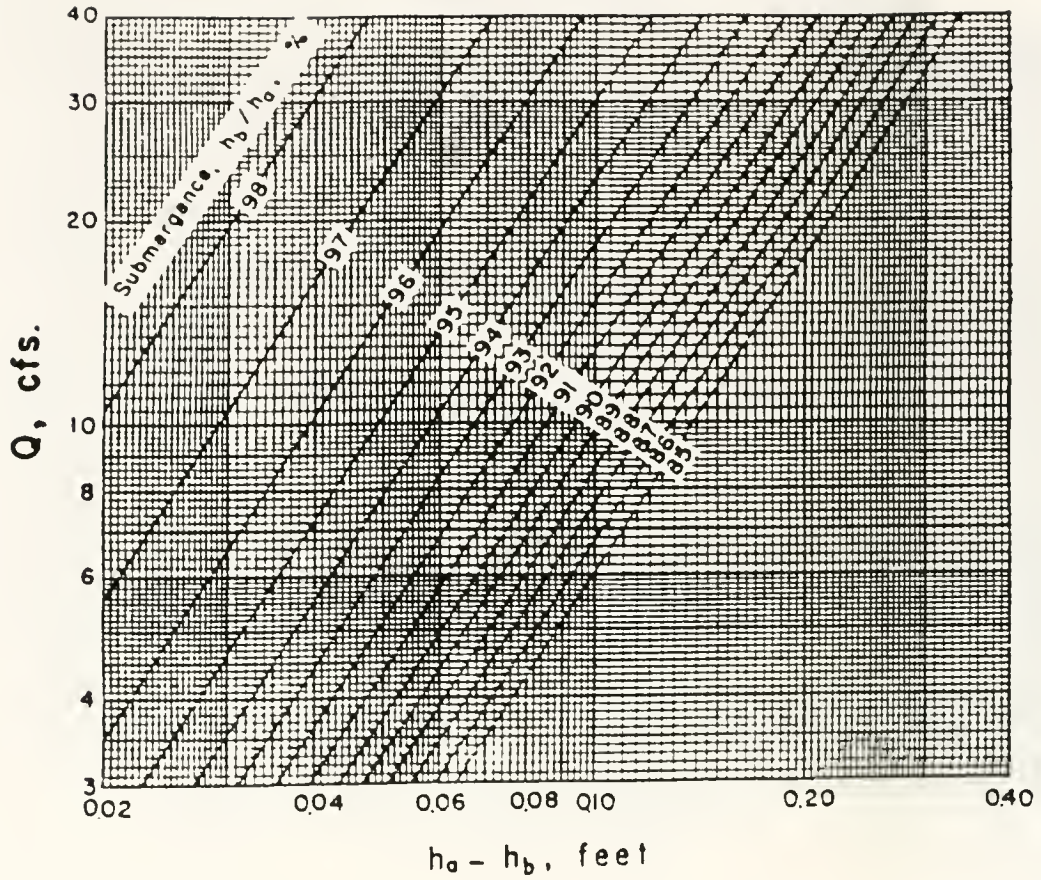


Fig. 10. Submerged flow calibration curves for 2.5-foot rectangular cut throat flume.



ig. 11. Submerged flow calibration curves for 3-foot rectangular cutthroat flume.

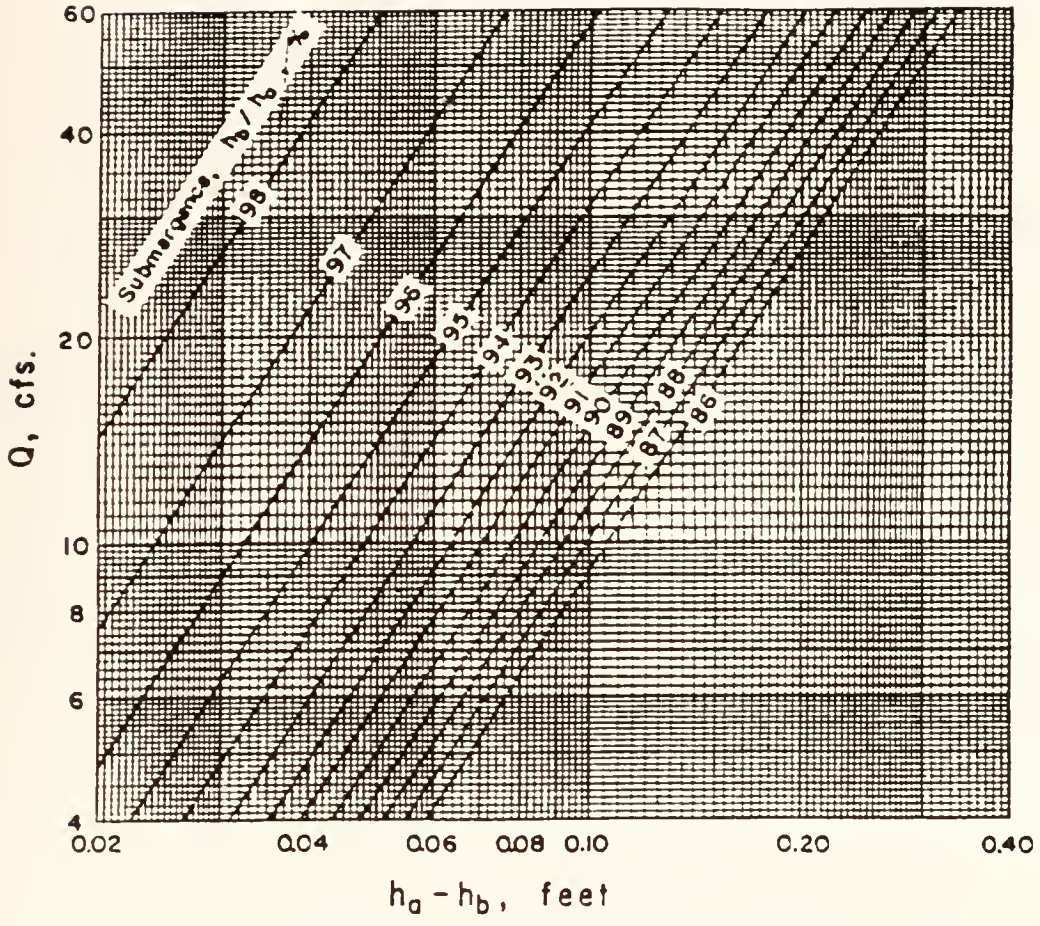


Fig. 12. Submerged flow calibration curves for 4-foot rectangular cutthroat flume.

INFORMATION SOURCES

INFORMATION SOURCES

This section is included in the manual because it is often necessary to contact individuals to obtain assistance in their specific field of expertise. Contained within this section are the names and addresses of those agencies that could most readily assist water commissioners and mediators with their technical or legal questions.

U.S. Department of Agriculture — 329-3315
Forest Service, Region 1
Federal Building
P.O. Box 7669
Missoula, MT 59807

U.S. Department of the Interior — 255-2913
Bureau of Land Management
Montana State Office
222 North 32nd Street
P.O. Box 36800
Billings, MT 59107-6800

U.S. Department of the Interior — 247-7308
Bureau of Reclamation
Montana Area Office
2900 Fourth Avenue North
Billings, MT 59101

U.S. Department of the Interior — 441-1319
Geological Survey
Federal Building
Drawer 10076
Helena, MT 59626

Montana State University — 994-6647
Extension Service
Linfield Hall
Bozeman, MT 59717

Montana Department of Fish, Wildlife and Parks 1420 East Sixth Avenue P.O. Box 200701 Helena, MT 59620-0701	444-2535
Montana Department of Environmental Quality 1520 East Sixth Avenue P.O. Box 200901 Helena, MT 59620-0901	444-2544
Montana Water Court P.O. Box 879 Bozeman, MT 59771-0879	586-4364 or 1-800-624-3270
Montana Department of Natural Resources and Conservation 48 North Last Chance Gulch P.O. Box 201601 Helena, MT 59620-1601	444-6601

INFORMATION SOURCES

Name	Address	Phone Number

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